

Investigating the effect of oil contamination on shear strength and sedimentation of clay soil

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Investigating the effect of oil contamination on shear strength and sedimentation of clay soil

First Edition

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Dedication

To my family

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Abstract

Leak of Crude oil from tubes, reservoirs and refineries related to the oil industry, as well as natural oil eruptions in some areas susceptible and its penetration into the surrounding soil and substructures in addition to destructive environmental impacts, such as contamination of groundwater and seawater, it causes changes in the geotechnical properties of the soil, as well. These changes are as change in physical properties and changes in the soil structure and texture in grain soils and in sticky soils, respectively. The problem of stability and resistance of soils contaminated with oil is important for structures, oil reservoirs, oil pipelines, and the stability of slopes. In this research, the geotechnical properties of soil impregnated with crude oil with two, four and six percent, in a period of ten, twenty and thirty days, have been measured by the results of direct shear tests, consolidation and single axial tests for clay soil. The results obtained for this study can be used as an application to prevent the soil damages.

CHAPTER

1

General Research

1-1 Introduction:

Man is hurting nature to achieve his short-term goals. Due to human activities, not only air and water but also soil is contaminated. Influencing the Earth in addition to causing contamination of underground water trips, causes changes in the status of the structures on the soil. Any change in the engineering characteristics of the soil layers can lead to reduced load capacity and increase the overall summation of the structural components. As a result, structures can be structurally ruptured or unusable for use. Contamination with crude oil can be from several sources. Of these, leakage from damaged transmission pipes, tanker accidents, depletion of seawater facilities, drought installations and natural leaks are more important. Also, the oil that has entered the water near the coast contaminates the whole coastline.

When leaks or oil spills occur, this hydrocarbon liquid is saturated with groundwater under the influence of gravity, so that its soil soils are semi-saturated. In spite of reaching the groundwater level, this liquid can contaminate more soil through horizontally released capillary forces.

Clay particles are chemically active. Their behavior is, in principle, dependent on the minerals of the particles that are affected by the environment. The particle environment contains the type of fluid in the specification and the type of ions present in it. Their behavior can change with the presence or diffusion of different fluids. The behavior of clay can be altered due to contamination with different types of fluids from different sources.

When leaking and falling oil, it is also contaminated by soil leakage. In these conditions, cost, time and energy must be spent to clean and refine the soil. Various methods have been proposed and implemented by companies and academies to refine and replenish contaminated soils. After disposing of oil lakes, these companies use contaminated soil at the substructure and road pavement, after mixing it with gravel stones. Also, large sites use burning method, biological methods, absorption methods, soil washing methods, vacuum separation and separation by centrifugation. We need to know that the method of decontamination from the soil directly goes

back to the depth of the penetration of contamination and the amount of environmental damage that comes into nature. Among these, the use of contaminated materials as building materials for pavement, as coating materials, seems to be more logical as a constituent of a landing. Because contaminated soil, in addition to getting away from the critical area, also finds value. Such use of soil requires the provision of a documented and credible document on the impossibility of causing environmental consequences. These consequences include the contamination of groundwater, evaporation and air contamination caused by it, and the effects of the persistence of such contaminations on human health and life. Therefore, the presentation of the environmental report is necessary before such projects, and it may be recommended by the monitoring organization to use a coating to prevent environmental contamination.

Figure 1-1 shows the sample of oil contaminated soil that occurred near the refinery of Isfahan due to the breakdown of the oil pipe.



Figure 1-1. contamination of dirt around the refinery of Isfahan due to the breakdown of oil pipe

1-2 Definition of the domain under review

1-2-1 Grain Soils

Most studies on soil plumage to crude oil and the effects of contamination on soil geotechnical properties on sandy soils have been carried out. In the results of all these studies there are some common points that are referred to below.

1-2-1-1 Compression

In general, what emerges from the studies indicates that the grain aggregates improve with increasing oil contamination. In these experiments, the modified prototype experiment was used in principle. The dry soil is mixed with a certain percentage of crude oil and is then dusted with a different amount of water and is dusted according to ASTM D698 standard. An example of a

change in the behavior of the sand against the change in the amount of oil is evident in the results of the tests by Al-Sanad, et al. in (Fig. 1-2).

The reason can be explained by the more effective reduction of the friction between the grains of sand and the closer position of the seeds to each other, if oil is used, and also the effect of oil lubrication on soil grains. Although field trials have not been conducted in these studies, laboratory experiments have been carried out that the concentration of oil contaminated with contamination of more than 6% is very difficult in practice.

Khamchian et al. (2006) believe that the compressive behavior of silty sand and badly graded sand is different. Capacity of SP samples, unlike SM sands, is not significantly improved. The mild dry weight loss in SP samples can be due to the large porosity between the particles and the possibility of moving the oil between them at an equivalent velocity of water velocity, and to equal the fluidity of the oil and water.

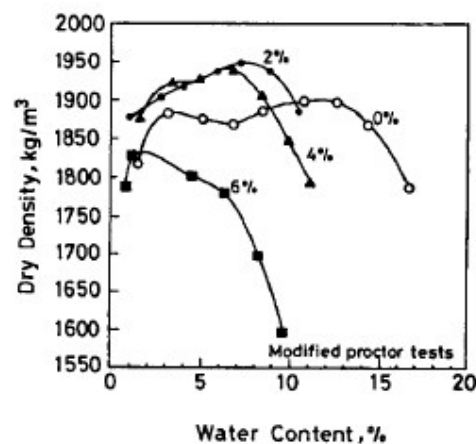


Figure (1-2) Density test charts for samples with different contamination percentages (Al-Sanad, et al.)

1-2-1-2 Shear strength

The internal friction angle Φ also decreases in the presence of oil in the inter-aggregate space based on general stress conditions. The observed variations in the internal frictional angle with the degree of oil saturation in Fig. 1-2 are shown. For experiments with a primary relative density of 85%, the friction angle decreases from 40° for dry sand to 30° when the degree of saturation of oil reaches about 19%. For experiments with a relative primary density of 40%, the friction angle of 35° for dry sand decreases to about 28° for contaminated sand when the saturation degree reaches about 19%. Therefore, the reduction in the friction angle is a function of the initial relative density of the sand and the initial saturation of the oil. Among the parameters studied, the decrease in the internal friction angle of about 20% to 25% was observed relative to the dry state with similar relative densities. For a certain degree of saturation of specific oil, the decrease in the internal friction angle was more pronounced for samples with a relative primary density higher. This decrease in the angle of internal friction affects the stability of slopes and structures constructed on them in water and in the land.

1-2-1-3 Consolidation Tests

Consolidation experiments on sand and sand mixed with different percentages of heavy crude oil. For this purpose, most of the samples that were saturated with water before the test were used. The results are generally presented in Figures (1-3) and (1-4). As can be seen, in the presence of oil, the consolidation meeting will increase. The compression index (C_c) from 0.03 for clean sand, to 0.66 for crude oil and 0.07 for heavy crude oil. The modulus of compression M ($\Delta p/\Delta \epsilon$) was moderate from MP 3/20 for clean sand to MP 2.9 with heavy crude oil and 4.9 MP for light crude oil. This compressibility, although not large, by contaminating crude oil more than doubles.

This has a compatibility with the findings of Meegoda & Ratnaweera (1994), which was derived from the sticky soil test. Mechanical factors such as viscosity, or fluidity, facilitate the slippage of soil particles on both sides, increasing the density index of soil.

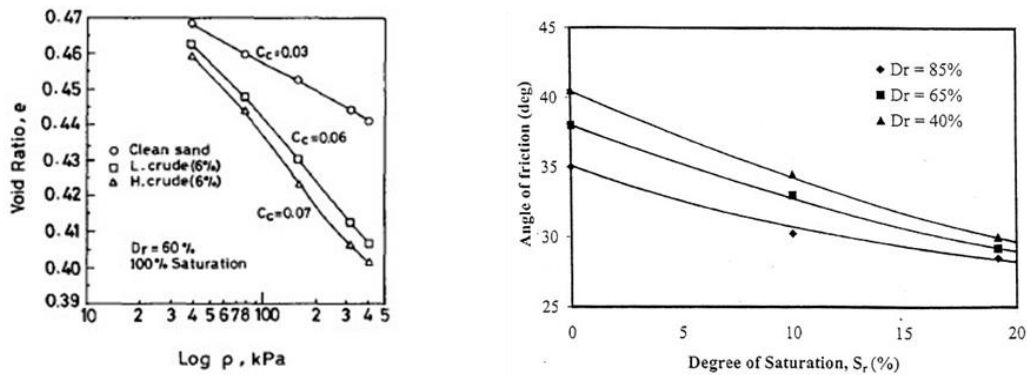


Figure (1-3) Internal friction angle diagram - Natural and contaminated saturation percentage,
Fig. 1-4 shows the porosity-pressure graph

1-2-1-4 Permeability tests

Continuous head permeability tests have been performed to investigate and compare hydraulic permeability. Certain amounts of sand are mixed with predetermined quantities of crude oil. Mixture of contaminated soil is in a pressurized permeability system. The relative density of sand is denser and the degree of saturation of variable oil is considered. Distilled water has been used as a penetrating liquid, and enough time has been given to the samples to ensure that there is no air between the particles of the soil and the constant flow of fluid. The results show:

- 1) For a relative density and specific contamination, k decreases with increasing the degree of saturation of the primary oil.
2. For the degree of saturation of oil and the type of contaminating material, k decreases with increasing relative density of sand.
- 3- For relative density and degree of saturation of specific oil, k decreases with increasing contaminant viscosity (Vijay K. Puri 2000).

1-2-2 Fine grains

1-2-2-1 Texture (Fabric)

The texture of a soil is related to the geometry of its particles. Together with specific gravity and initial stress, tissue is an important parameter for controlling the characteristics and behavior of soil engineering. Soil scanning was studied by electron microscopy of soil texture. In the following, a variety of tissues are indicated for contaminated clay and clay, and they are considered signs to be assigned to the following materials.

1-2-2-2 Non-contaminated clay

Fig. 1-5 shows the non-contaminated clay micrograph with a magnification of 10,000. Smectite patches and Palygorskite tubes are shown in the figure. At this magnification, a non-folk tissue was observed. No specific set showing the structure and texture of the follicles can be seen in this micrograph.

1-2-2-3 Clay contaminated

Figure (1-5) b is the micrograph obtained by scanning an infected sample by an electron microscope. The size of the palygorskite tubes in the contaminated clay is noticeably larger than non-contaminated clay. The reason for this is the capture of single particles and cluster particles with particles of oil. Sets that form in this way have silt sizes or even sand. The mechanism of this interaction between clay and oil is shown in Fig. 1-6.

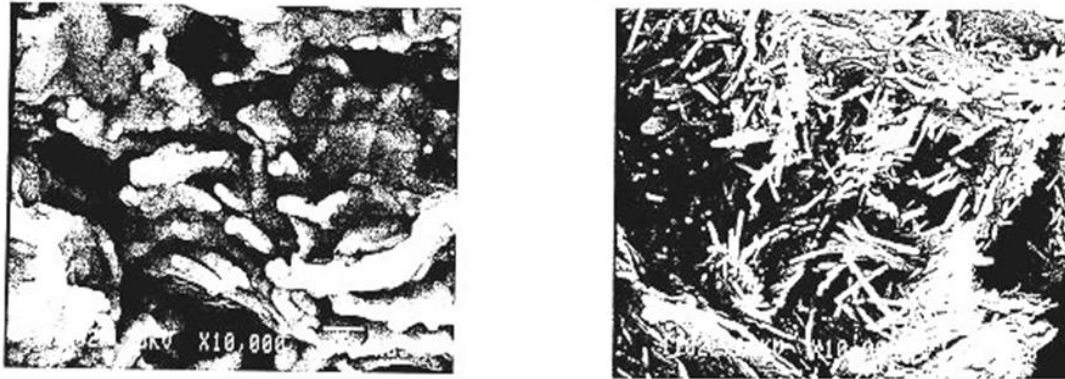


Figure (1-5) The micrograph obtained by scanning a sample of the clay using an electron microscope (Habib ur rehman 2007)

A) non-contaminated clay

b) clay contaminated

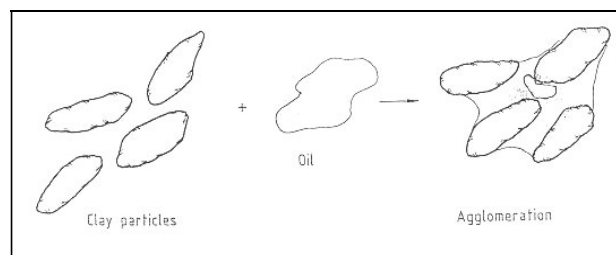


Figure (1-6) schematic model for infected clay texture

1-2-2-4 Infused clay and added water

When the water was added to the oil-infused loose mixture, it was observed that the water separates the oil and clay bond. A schematic model for this topic is shown in Fig. 1-7. Distilled water used in this study has the ability to separate ionic compounds due to its high dielectric constant (80). Now this tissue can be considered as a scattered tissue.

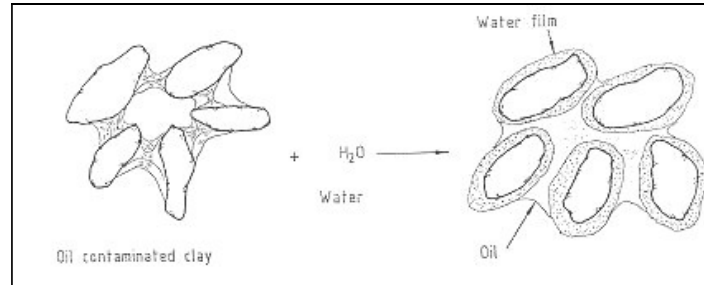


Figure (1-7) schematic model for contaminated clay texture and added water

1-2-2-5 The Atterberg limits

The addition of crude oil increases the Atterberg and the psychological index. The most probable reason for an increase in the Atterberg range is the excess adhesion added to the clay particles by oil. Therefore, excess water should be added to the soil in order to ensure the thickness of the double layer to change the condition of the soil.

1-2-2-6 Compression

When the soil is to be domestically condensed or used as a gravel aggregate, its compactness should be certain. In this research, a standard protractor test was used to determine the condensation characteristics. For contaminated soils, dry soil specific gravity is considerably higher than non-contaminated soil and has achieved relatively less moisture content. Since the particles and seeds are covered by oil, this pollutant acts as a very strong lubricant and results in a very high specific gravity in a very low moisture content. In Fig. 1-8, these results are visible.

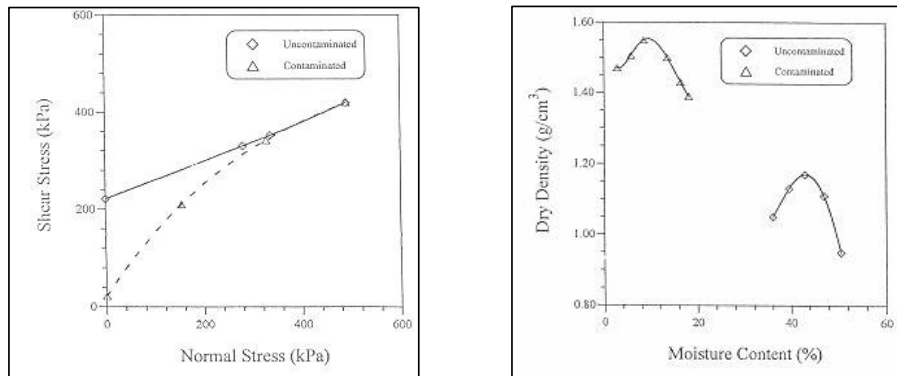


Figure (1-8) The relationship between density and moisture content, Figure (1-9) of Mohr-Columbian clay for infected and non-contaminated clay

1-2-2-7 Shear strength

The shear strength, as it affects the bearing capacity and also the stability of the foundation system in civil engineering structures, is a very determinant parameter in the soil. The shear strength considered for comparison is the resistance obtained from the undrained triangular pressure test of the drainage system. The sample size used for this test is 1.5 centimeters in diameter and 10.2 centimeters in height. The specimens were dried up to 12 kJ / m³. The results of this experiment are shown in Fig. 5, which shows that in all-round tensions, the contamination of the soil is less than that of non-contaminated soil, while in the limiting tensions, the resistance was slightly higher than the non-contaminated soil resistance.

An increase in the clay content of the mixture with oil can be due to the accumulation of particles in the presence of oil. Therefore, the tissue tested for resistance is type F-2 (infected clay texture). In all-round tensions, the resistance is reduced due to the formation of large-sized particles, the reduction of the specific surface area and, consequently, the reduction of adhesion, which can be clearly seen from the Mohr-Columbian case (Fig. 1-9). In all-high tensions, the resistance is relatively high, which indicates the dependence of the resistance of the oil-infused clay to the total stress.

1-3 Statement of Research Objectives

Oil spill occurs for a variety of reasons, including leakage from underwater reservoirs, oil tankers accident, natural leakage, and so on. Oil spill causes soil contamination and changes the geotechnical parameters of soils. It also affects the physical and mechanical properties of crude oil contaminated soils, slope stability, bearing capacity, and other structures. In this research, we tried to study the geotechnical properties of soil based on experiments on oil-contaminated soils.

1-4 The importance for research

During the last decade, a number of investigations have been conducted on the relationship between the physical characteristics and the behavior of the oil-contaminated soils (or with oil). However, further research leads to the identification of other relevant factors in geotechnical engineering. Although the number of published researches but their results indicate that the fracture angle of total soil stress decreases when oil is contaminated with oil. Many oil spills also contaminate low-depth soils. When the soil undergoes oil contamination, capacity The final bearing and the angle of fracture of the soil are reduced.

1-5 Research applications

Oil is one of the most widely used hydrocarbon materials. This fluid is stored or transmitted in a variety of ways due to its high application in this place. Hydrocarbon contamination leakage may be due to reasons such as leakage from tanks, old and decay transmission lines, explosions, natural disasters such as earthquakes and damage caused by artificial factors such as accidents. Oil leakage causes soil and water contamination, and soil contamination causes changes in its geomechanical characteristics and can subsequently change the slope stability, loading capacity, and so on.

Soil contamination to petroleum and its effects on soil engineering in different parts of the world, including in oil-rich countries. By conducting this research, designers are able to make important decisions in contaminated areas by adopting a reliable coefficient of occurrence. Because of their solubility, volatility and bio-degradability, oil hydrocarbons are one of the most common pollutants in the environment and are known for many toxic substances that are found to

be flammable through refineries, fluids, or leaks from underground fuel tanks , enters ground and groundwater and endangers their health, and threatens human health and the environment.

CHAPTER

2

An overview of the research literature

2-1 Introduction

The study of the effect of soil contamination on crude oil has been carried out since 1992 by various researchers. In these studies, soil with different weight percentages (oil / dry weight ratio) was tested with mixed oil after a period of from one week to one month. A variety of gravel and clay soils, oil with specification (from Specific gravity and specific gravity) and different parameters have been tested. The following table shows the most significant studies conducted since 1992 in this field. The type of soil and the parameters tested are also specified in this table.

2-2 Review of previous articles

A summary of the research carried out in Table (2-1) is given below.

Table (2-1) Summary of research carried out in the field of research

Researcher	Soil Type	Year	Tested parameters	
Hashim Mohamed et	Clay-Sand	2013	Atterberg limits, Condensation, Consolidation, CBR, Tensile Pressure	1
Ashraf K. Nazir	Clay	2012	Influence of soil oil contamination on the Atterberg limits, pressure unconstrained force, permeability coefficient and compression index	2
Ijimdiya,T.S. and Igboro, T.	Clay	2010	The behavior of soil-contamination in oil	3

Ahmed M. A. Nasr	Sand	2009	Theoretical and experimental studies on the effect of oil spill on the pivot column alignment	4
Ur-Rehman,Habib et	Clay	2007	Basic and advanced geotechnical tests, cation displacement capacity, inflation pressure	5
khamchichyan,M et	Clay-Sand	2006	Atterberg limits, density, straight cut, single axial pressure, permeability	6
Shah, Sanjay J et al	Clay-Sand	2003	Stabilized by lime, cement and FlyAsh and tested c, Φ , σ_c	7
shin, Eul Chun et al	Sand	2000	Shear strength (direct shear test), permeability	8
shin, Eul Chun et al	Sand	1999	Shear Strength (Direct Cutting Test)	9
Meegoda, Jay N. et	Gravel-Sand	1998	Comparison of the effects of polar and nonpolar pollutants on crop behavior	10
Al-Sanad, Hasan A.	Sand	1997	Direct cutting, three axial, consolidation	11
Prakash, Shemsher	Sea Sand	1997	Static geotechnical specifications	12
Al-Sanad, Hasan A.	Sand	1995	Basic specification, density and permeability, three axial and consolidation, direct cutting	13
Tuncan, A. et al	Sea Clay	1992	Physic-chemical characteristics, ductile properties, microstructures, shear strength, hardness, permeability, compressibility	14
Cook, E. E.	Sand	1992	Compaction, shear test, single axial pressure	15
Pamuku, Sibel&...	Kaolinite clay	1992	Stabilized by lime, cement	16

2-2-1 An overview of published papers

Impact of time on Kuwait's sandy soils contaminated with crude oil

(Hasan A.Al-Sanad and Nabil F.Ismael 1996)

The tests carried out include direct cutting, three-axial and consolidation.

Contamination and sample storage conditions: Soil prepared from the site is mixed with oil in proportion to 6% of the dry weight of the soil and is stored in galvanized containers at an external temperature of $1 \times 1 * 0.2$ for 6 months. The experiments are carried out to The intervals of 1.3 and 6 months have been taken from the sample.

Result: During 6 months, due to the volatility of the oil, the soil becomes harder, although this hardness is less than that of non-polluting soil, the increase in the friction angle of the soil from 28 to 32 within six months and an increase of 17.5% of resistance during this period 11 percent less contamination-free. Increasing soil compaction is another result of this research.

Effects of Oil Contamination on Soil Properties in Bushehr

(Mashallah Khamhchian and Amir Hossein Charkhabi and Majid Tajik 2006)

The experiments included: granulation, roundabout, compressibility, direct cutting, non-junction compression force and permeability

Type of soil examined: SP, SM, CL

Contamination and preparation of samples: 14 specimens are sampled at a distance of 3 km from the soil on the coastline of the soil, with a sampling diameter of 30 cm. The sample was obtained with an infection rate of 4.8, 12%, 16% Raw mixes

Examination: Concentration, granulation distribution, PH and electrical conductivity

Geotechnical behavior of fine-grained soil with oil

(Habib-ur-Rehman.Sahel N, Abduljauwad, Tayyeb Akram 2007)

The experiments consisted of: Atterberg limits, density index, unencumbered three-axial undivided, one-dimensional consolidation, inflation percentage

Type of soil examined: CH

Sample preparation: A swab sample prepared from the site washed to allow the grain to pass through a sieve number 40, then the sample is completely saturated with crude oil to reach a dry concentration of 12 kN / m³, then the sample is taken for one week It's dry Theoretical and laboratory studies on the behavior of strip pillars on crude oil contaminated sand (Ahmed M. A. Nasr 2009)

Case studies: Bearing and static capacity

Sample preparation: Mixture of sand with 0-5% crude oil

Result: Seismic behavior and final bearing capacity of the column are significantly increased. The increase in the depth of the sandy sand layer results in an increase in the coefficient of seismicity along the depth of the sand layer.

Effect of Soil Oil Contamination on Soil Geotechnical Specifications

(Zulfahmi Ali Rahman, Umar Hamzah, Mohd. Rahan Taha 2010)

Type of soil examined: SP

Experiments performed: Atterberg limits, compression, permeability, unconsolidated undifferentiated three-axial

Contamination and preparation of the sample: The sample is mixed with 0-4% crude oil.

Conclusion: Reducing the amount of fluid and the amount of dough, reducing the dry concentration and saturation percentages and reducing the permeability are other results of this study.

The behavior of the soil contaminated with oil

(Ijimdiya,T.S. and Igboro,T. 2010)

Type of soil examined: brown-reddish CL

Experiments performed: grain distribution, unconfined compressive force USC, cv coefficient of condensation, volume density coefficient Mv and porosity coefficient

Percentage of contamination and sample preparation: Mixing of dirt soil in a depth of half a meter of ground prepared with 2,4,6 percent crude oil

Conclusion: There is a significant reduction in the amount of aggregates in high concentrations of contamination, reduction of unconfined compressive strength and porosity coefficient, increase of density factor and consolidation coefficient.

Influence of oil contamination on granite and sedimentary deposits

(Zulfhmi Ali Rahman , Noorulakmabinti Ahmad 2011)

Specifications of soil type:

Granite: clay 4%, silt 33%, sand 38%

Sedimentary: 29% clay, 43% silt, 4% sand

Experiments performed: Atterberg limits, special weight, density, UU undiluted undiluted shear strength and aggregate distribution

Percentage of contamination and sample preparation: adding 4.8,12,16% crude oil to the dirt soil prepared from the site

Conclusion: By increasing the percentage of contamination in the Atterberg range, the maximum dry concentration, optimal water content and undiluted drained shear strength are undiluted.

Influence of soil oil contamination on pre-consolidated clay (Ashraf K. Nazir 2011)

Type of soil examined: pre-consolidated clay

Experiments performed: Atterberg limits, unpressurised pressure force, permeability coefficient and compression index

How to make the sample and the percentage of contamination: Putting intact soil obtained from the site inside the tank and applying the pressure of 65 kPa and then mixing with crude oil to create the actual environment conditions

Conclusion: The 38% reduction in the unpressurised pressure force compared to normal, as well as the reduction of the Atterberg limits during the three months of contamination, increased permeability and insignificant impact on the consolidation coefficient were other results of this study.

The Impact of Oil Contamination on the Properties of the Clay of the Delta of the Nigerian Region

(Adejumo T Elisha 2012)

Type of soil tested: soft clay Nigeria area case study

Experiments performed: Atterberg limits, porosity, undiluted shear strength undiluted

How to make the sample and the percentage of the contamination: The sample is taken from the contaminated environment and the relevant tests are carried out.

Result: Dry soil concentration in the non-contaminated state is $14 \text{ kN} / \text{m}^3$, 17.9% in the infected state is increased at the psychosocial level and 6.9% increase in plastic content is another result of this study. Also, porosity and inflation is also reduced.

Influence of oil contamination on clay and sand characteristics

(Hashim Mohammad Alhassan, Sabiu Abdullahi Fagge 2013)

Type of soil studied: clay, residual soil from sedimentary rock, friction sand
Experiments performed: Atterberg limits, density, consolidation, CBR coefficient, three-axial pressure

How to make the sample and the percentage of contamination: mixing 2,4,6 percent low-density oil with dirt soil prepared from the site

Result: Increasing the shear strength of sedimentary and sandy soils, as well as increasing the resistance of clay in the percentage of contamination of 2 and 4%, and decreasing resistance in percentage of contamination of 6%

Reduction of the CBR coefficient in all three soil specimens as well as increasing the concentration of all three samples, which decreases with increasing levels of contamination.

Result:

In all percentages of contamination, with time, the psychological limit and the dough limit are reduced. Concerning the compaction characteristics, increasing the percentage of contamination reduces the optimum moisture content and increases dry weight, but with increasing lifetime of the contamination, decreases the optimum moisture content and increases the specific weight It is dry but increasing the life of the pollutant in all percentages of contamination increases the optimum moisture content and dry soil specific gravity.

CHAPTER

3

Introducing the tools and materials studied

3-1 Introduction of used soil

In this study, in order to achieve the role of soil contamination on the soil resistance and concentration of soil in the Babylonian area, from the site near the laboratory, from a depth of one meter about 50 kg of soil was taken away. At the laboratory site, identification tests were carried out on the soil. The soil is obtained from the clay site with low plasticity, which we give to the results of the experiments below.

3-1-1 Segments

Soil granulation testing is performed according to ASTM D422 standard. According to this standard, soil grains for seeds larger than 75 micrometers (residue on the sieves of 200) by sieving and for sieves smaller than 75 micrometers (passage from No. 200) by performing a hydrometric test and observation The seed sedimentation process is determined. The plot of soil gravel, as well as the graining percentage table, are plotted in Figures 1-3 and 2-3.

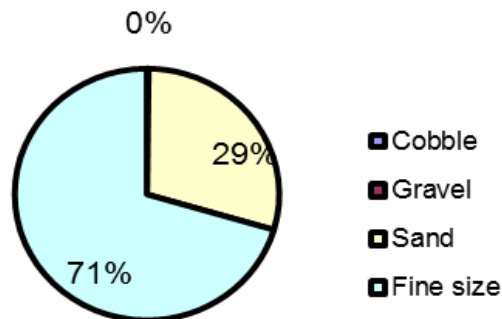


Figure 1-3 shows the percentage of fine grain and coarse soil used in the soil

Table (1-3) The characteristics of soil partition utilization

Passing sieve No. 4	29.0	Cu	56.77
Passing sieve No. 200	71.0	Cc	0.21
D10	0.001	LL	23
D30	0.004	PL	15
D50	0.015	PI	8
D60	0.068	Soil Type	CL

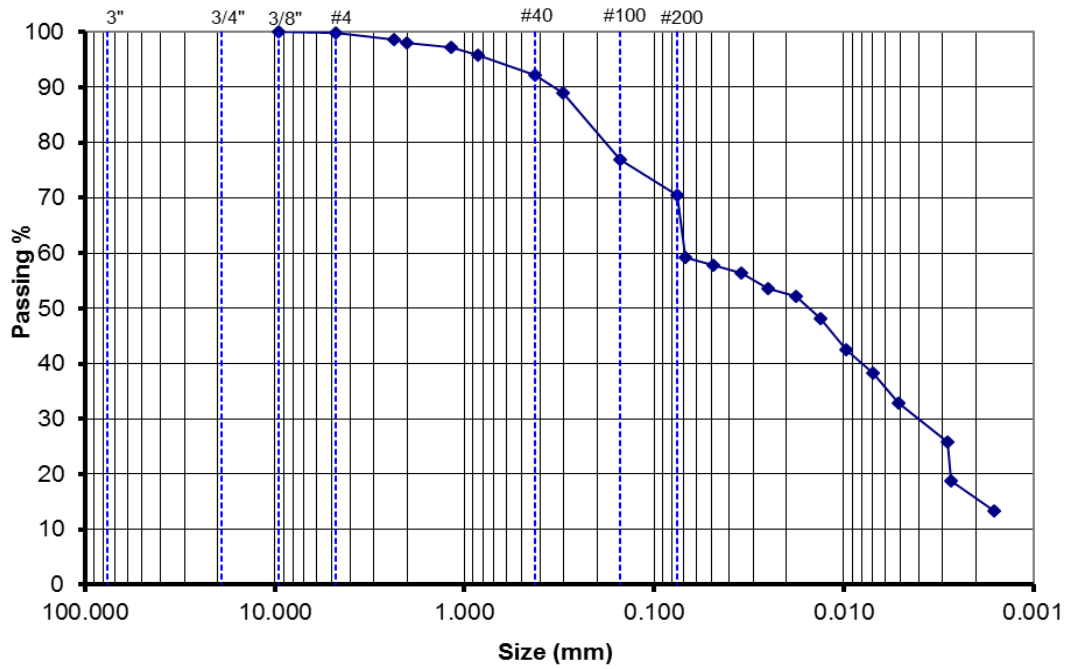


Figure (2-3) The soil plotting chart

3-1-2 Atterberg limits

This test is in accordance with ASTM D 422 -63 standard. The curve and table of the numbers obtained from the experiments (2-3) and (3-3) are given.

Table (2-3) The values of the Atterberg limits

Liquide Limit (LL)	25
Plastic Limit (PL)	15
The plasticity index	9

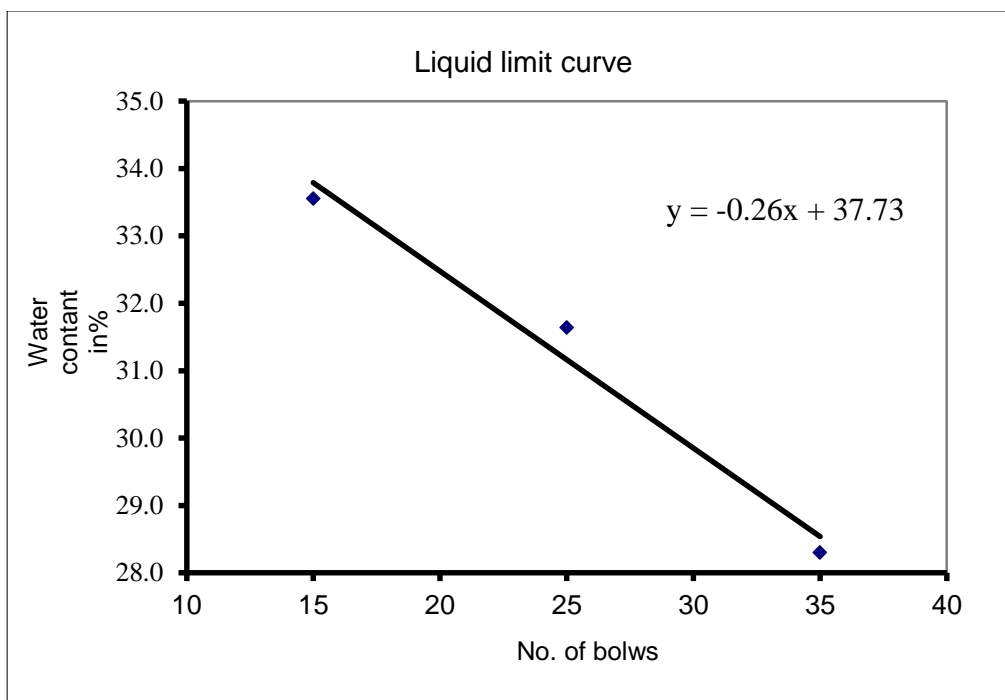


Figure (3-3) Liquid Limit Curve

3-1-3 Specific gravity (Gs) and moisture content

Soil from the environment was immediately tested for specific moisture content and density, and the values obtained in Table 3-3 are given.

Table (3-3) Specific Density and Moisture Density

Specific Density (Gs)	2/71
Specific Density	20/03

3-1-4 Equivalent sand (Density in place)

This test has been carried out according to ASTM D 2419-09 and aims to determine the percentage of soil compaction for the preparation of samples to match the soil density at the site. Data and results from this experiment are presented in Table (3-4).

Table (3-4) The values obtained from the equilibrium sand test

Maximum dry weight	Ydmax	2.20 gr/cm ³
--------------------	-------	-------------------------

Log Number	Soil Weight	Sand Weight	Volume	Special Weight	Moisture percentage	Special Weight	Percentage of density
	Wet(gr)	Wet(gr)	Cm ³	Wet(gr/cm ³)	%	Dry(gr/cm ³)	%
A	1445.3	1333.0	888.67	1.40	19.79	1.17	53.07

3-2 Specifications of consumable oil

The oil used in this study is to contaminate the samples from the Isfahan refinery, which is described in Table (3-5).

Table (3-5) Specifications of consumable oil

92/14	Viscosity at 10 ° C
2/2	Dielectric constant
33/88	API
0/8556	Specific gravity at 15.56 degrees Celsius

3-3 Single-Axial Test

Single-Axial test is used to determine the shear strength of sticky dirt or sticky-frictional soils. The mono-threaded device used has a 5 KN with an accuracy of 0.5 N, which is connected to the top of the device and displays the load force with a precision of 0.1 kg. The loading process of the device is a strain control with a variation of 1.27 mm/min. Figure (3-4) shows the monochrome device used in the test.



Figure (3-4) Single-Axial test machine

Sample preparation is carried out in such a way that the soil is removed from the nylon during the test and is completely mixed with a spatula. Then, in a CBR cone, it is poured into three layers, and then we thicken it by hammer, depending on the density of the medium, then by the mold A single-axial machine will sample the soil carefully and the sample obtained will be tested in nylon

to prevent dryness and loss of moisture. It should be noted that the diameter of the specimens is 38 mm and the height is 76 mm, as seen in figure (3-5) of the device with the sample.



Figure (3-5) of the unidirectional device along with the sample being tested

3-4 Direct shear test

Direct shear test is one of the other soil mechanics experiments in determining the resistance behavior of soil. Due to its simplicity and economic justification, it is widely used. Although the biggest disadvantage of this test, the definite defect of the fracture plate along the separation plate of the two upper and lower sections of the template includes the specimen, however, despite the uniformity of the granulation and the homogenization of the specimen during construction, does not seem to be This defect is a fundamental problem in the results of the test. The direct shear test, which was proposed for the first time in 1776 by Coulomb, is the oldest shear test. This test is the most commonly used method for determining the shear strength of drainage (shear strength based on effective stress) in non-adherent soils. This test can also be performed on sticky soils. The shear strength obtained consists of three parts:

- 1-Adhesion between soil grains (C), which is inherent in soil grains and independent of external forces.
- 2- The frictional resistance is proportional to the vertical stresses acting on the slip surface (σ_n)

and the angle between the soil grains called the internal friction angle (ϕ).

3- The clogging of soil grains decreasing in high enclosure stress due to breakage of sharp points of grain aggregates, fracture of self-components and also the smoothing of components at the contact point.

4- The shear strength of the soil is essentially expressed in equation (3.2). This equation is called σ - τ in the coordinate system and represents a line whose slope shows the amount of adhesion relative to the horizon, the internal friction angle and the width of its origin.

$$\tau_f = c + \sigma_n \cdot \tan \phi \quad 1-3$$

In this test, there are three methods based on the determination of drainage conditions. In a non-drainage test (UU), the shear of the sample before the soil is consolidated under the influence of vertical pressure, it will be started. For a drainage test (CU), shear force is not applied until the sample is subjected to vertical load stresses. For a drained consolidated test (CD), the sample is not started to crack until the port is stopped; then the shear force should be applied to a degree that does not require any additional cavity pressure in the sample. Do not be That is, if the specimen showed a tendency to dilate, there should be sufficient time for water to enter the sample, and vice versa, if the sample showed a tendency to density, there should be sufficient time for the water to flow out of the sample.

3-4-1 Description of the direct shear test device and the necessary equipment

The direct shear device, which is shown in Fig. 3-6 is composed of different parts, the description of which is described below.



Figure (3-6) Direct shear device view

3-4-1-1 Shear box

It consists of two half-boxes with a circular or square metal section. The upper half of the test is constant and the lower half of it is displaced by applying horizontal displacement. There are four screws on top of the upper box, two of which are for fixing the two half boxes together while placing the sample in a box and two other to adjust the friction between the two half boxes during the cutting. After the sample is placed in the box and before the test, the two screws are fully opened.



Figure (3-7) and (3-8) components of the shear box

3-4-1-2 Porous stones

The genus of these rocks is chosen to be of good resistance to soil and water. The porosity of the stone should be proportional to the size of the soil grains. In other words, it is so coarse that it can create the proper dirt and is so tiny that the seeds of the soil cannot pass through it. These rocks, along with the mold and other components, are shown in Fig. 3-9.



Fig. 3-9. Porous stone, Direct shear machine

3-4-1-3 Loading equipment

- Equipment for vertical load measurement

The vertical force is applied by a lever loaded with pneumatic load or equipment. This equipment must be able to hold the load in a range of 1% of the required load.

- Sample shear equipment

This equipment should be able to cut samples at a uniform rate with less than 5% + oscillation. Additionally, the displacement rate should be adjustable within the range of 0.05 to 2 mm/min. The test speed depends on the strength of the sample. The shear force is generally applied by an electric motor and gearbox to the specimen and measured by a rim or load cell. The upper cut box weight should be less than 1% of the vertical force applied. In this case, the weight of the upper box should be neutralized by an equilibrium weight. Figure 10-10 shows the shear-off box.



Figure 3-10 sample shear equipment

The loading device in this test is a set that provides the ability to apply vertical force and shear force. The right vertical force after insertion of the shear box is usually carried by placing certain weights on the hanger to the upper level of the sample. For uniform distribution, a metal bullet and a cast-iron cap are placed on the sample.

Double shear force application is possible: First, shear force is applied in such a way that the transfer rate is controlled. This feature is available using an electric motor and gearbox. The shear force is shown by the nylon ring. The cutting step continues until it reaches a displacement of 10 to 20% of the initial diameter of the sample or the back of the knife.

In the second case, the shear force is applied incrementally. A cable is connected to the upper half of the cut box. This cable is connected to a pendant through a wheel and loads into the pendant. By adding the weight to the hanger, the shear force increases. With increasing horizontal variation of the sample, lighter weights should be added to the hanger. When the shear strength of the sample is reached, the specimen is rapidly divided into two halves.

Among the two methods, the controlled method is more commonly used for strain.

3-4-1-4 Technical Specifications of the Machine

- 4x16 display with backlight
- The loading speed is equal to 0.5 mm/min
- The gearbox has a power output of 200 watts
- PC connectivity with RS 232 port
- Show actual force and maximum force based on N
- PLC control system
- Includes motion limiting microswitch
- Software calibration
- An indicator clock with a rating of 20 mm and a precision of 0.01 mm to measure the displacement of the horizontal (shear)
- With an indicator clock of 5 mm and a precision of 0 mm for vertical displacement measurement (density)
- Has software overload to shut down the system

3-4-2 Description of the testing process

In this study, with the aim of evaluating the effect of oil with 2, 4 and 6 percent on soil, at 10, 20, and 30-day periods, a total of 9 experiments with contamination and a non-contaminated soil test were performed using direct cutting tests, the results of which The following chapter is outlined The specimen made for this test is similar to the single-axial test sample, with the exception that direct cutting was used to make the soil. The samples obtained in two layers of nylon were placed to prevent moisture. Then, for each time period and contamination, three direct cutting tests with loads of 1, 3 and 5 kg were performed according to ASTM D 3080.

The normal stresses applied in this test are 17.5, 37.5 and 57.5 KPa, and the shear rate is 0.5 mm/min.

3-5 Consolidation test

Saturated soils and organic soils are resistant to sediments due to the large amounts of stable load. These are often direct structural weights that cause the sinking of organic and sticky soils, but

secondary factors, such as lowering groundwater levels, can cause sinking. Saturated or organic clay soils have three different components: immediate, primary and secondary sedimentation. Figure 3-11 shows the consolidation device. This test provides a method for determining the amount and speed of consolidation of a soil in adjacent enclosed conditions with vertical drainage under stress loading. Two methods have been proposed:

The first method:

In this method, the test is performed with constant loading steps for 24 hours or a coefficient. In this way, time reading according to the settlement is required for at least two loading steps.

The second method:

Time reading is done according to the settlement for all loading steps. Loading after the time required for 100% initial consolidation or after a fixed period-similar to the first method.



Figure (3-11) consolidation device

Some tips for more considering:

1. This test is usually performed on saturated soils.
2. Usually the length of time that each weighing is on the device is one full day. For soils with a higher permeability than clay, such as dense clay, the steps can be shorter in shorter time depending on the shape variation.
3. At each stage, the load doubles. The main reason is that the results are shown semi-logarithmically, and the distance between the points will be equal in this case. Also, the weights of this machine are designed for this type of loading.
4. If after one day the deformation has not stopped yet, the load can be kept one day on the sample. But it should be noted that the curve slope (deformation-time) is not very smooth. In that case, the deformations are related to the secondary consolidation and the next step can be loaded. The purpose of the Consolidation Test is to determine the effective parameters in predicting the intensity of the sediment and its amount in the structures based on clay soils.

3-5-1 Experimental equipment

3-5-1-1 Loading equipment

Equipment suitable for vertical load (total stress) to sample This equipment should have the ability to apply load for a long time with a precision of $\pm 0.5\%$ load, and can also increase the load without significant impact to a certain amount.

3-5-1-2- The format of consolidation

This template holds the specimen inside a loop, on both sides of which is porous rocks. The inside diameter of the ring should be measured at 0.075mm. The reinforcement mold should also have the capability to submerged the sample, transfer vertical load to porous rocks and measure sample height changes. The minimum diameter of the sample should be 10 times the diameter of the largest aggregate.

The rigid rings around the sample should be such that, under the hydrostatic conditions in the specimen, the diameter change of the sample is less than 0.03% of the diameter under the most load. The rings around the sample should be of a sex that does not have a corrosive contact with the tested soil. The interior surface of the ring should be completely polished and either polished or coated with a low friction material. Use of silicon grease is recommended for this purpose.



Figure (3-12) consolidation device parts

3-5-1-3 Porous stone

Porous rocks should be of the same type as silicon carbide, aluminum oxide or non-corrosive materials. Porous stone particles should be small enough to give rise to the penetration of soil into their pores. If necessary, the filtering paper can prevent the penetration of the soil into porous stone pores. However, the penetration of porous rocks and filter paper (if used) should be at least twice the permeability of the soil sample. The diameter of the upper porous rocks should be about 0.2 to 0.5 millimeters less than the diameter of the inner circumference of the sample. The thickness of the porous rocks should be such that it does not break. The upper porous rock is

loaded with a rigid plate with sufficient corrosion resistance to prevent it from crushing. Porous rocks should be clean, free from cracks, fluttering and mild. Porous stones should be boiled in water for 10 minutes before use and then left in water until it reaches the ambient temperature. Each time immediately after the use of porous rocks, these rocks should be cleaned and boiled with a soft brush to allow its pores to remain. It is recommended that porous rocks are not used in some cases. These rocks are in a container containing no air to be kept.

3-5-1-4 Displacement Configurator

To measure the change in the thickness of the specimen, you need a 0.01mm accuracy gauge. You can see the shape in Fig. 3-13.

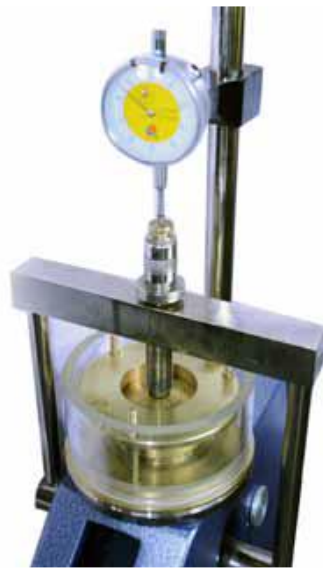


Figure (3-13) Configurator displacement device

3-5-1-5 Sample payment equipment

To prepare small intact samples, larger cylindrical or circular shear rings can be used. The shear ring should have a sharp edge with a perfectly polished inner surface. The inner circumference of the cutting ring should be exactly the same as the inner diameter of the ring around the sample and be able to connect to it. The inner surface of the shear ring should be coated with a low friction material. If using a rotary table, the shear tool should be such that the diameter of the sample is exactly as large as the inner diameter of the ring.

3-5-2 Test process

Sample preparation is prepared according to the planned time to open the corresponding nylon neck with 5 and the percentage of sample contamination of the day before loading. It will be saturated for 12 hours. Sample preparation, such as single-axial samples and cutting Direct supply is the only difference between the consolidation template for consolidation, which does not require a sample, and is fitted with a mold in a special enclosure for consolidation. Samples are loaded and loaded for this test in accordance with ASTM D 2435 standard.

The loads used for loading are 0.5, 1.2, 4.8 and 16 kg, respectively, and the loading is descending,

which in general each sample is loaded and loaded in the consolidation device for 11 days. In the corresponding time, vertical displacement is observed.

3-6 Designing experiments

After initial experiments to identify the soil including grain size and specific gravity of single axial test with the aim of investigating the effect of oil on the single-axial resistance of contaminated soil to percentages 2, 4 and 6 in the time interval of 10, 20 and 30 days and compare it With soil without oil. Also, direct shear testing to determine the shear parameters of the soil in the presence of petroleum products with the percentages mentioned above and the same time interval as the single-axial test was carried out. It is worth noting that the experiments performed with maximum accuracy and multiplicity have been done to reduce the errors. Which examples are presented in their tables in the next chapter.

Another test, which is carried out to evaluate soil infiltration and its comparison with soil in a normal state, is a consolidation test in which soil infiltration parameters are obtained and compared to non-contaminated soil. Table (3-6) summarizes the experiments conducted in this study.

Table (3-6) The experiments conducted in this research

Period (Day)	Oil contamination (%)	Type of test
0	0	Single Axial Test
10	2% ,4% ,6%	
20	2% ,4% ,6%	
30	2% ,4% ,6%	
0	%0	Direct shear test
10	2% ,4% ,6%	
20	2% ,4% ,6%	
30	2% ,4% ,6%	
0	%0	Consolidation Test
10	2% ,4% ,6%	
20	2% ,4% ,6%	
30	2% ,4% ,6%	

CHAPTER

4

Results and discussion

4-1 Introduction

The results of the experiments carried out in this chapter have been presented and evaluated and analyzed. In this research, the amount of oil contamination and the time interval of its effect are considered as a variable. Single-axial and direct shear tests were conducted to evaluate the shear strength of the soil clay behavior against contamination and duration by these materials. Also, for assessing the soil's susceptibility to contamination, the Consolidation Test has been conducted for all percentages of contamination and time spans mentioned in the previous chapter. In the following, the results of the contamination in the time interval are presented separately and discussed.

4-2 Analysis of the Effect of Oil Contamination on the Single-Axial Resistance of Soil

This test is similar to the three-axial test, except that it's not in the cell.

So:

$$\sigma_3 = C_{te} = 0$$

In this test, the speed of the pressure is controlled by hand and stopwatch. The experiment continues until the complete failure of the sample and then the stress-curve is plotted. The result of this experiment is the calculation of soil drainage adhesion.

In this study, soil with 2, 4 and 6 percent ratios were contaminated with oil and stored in two layers of nylons to maintain the soil's primary moisture content. During the period of 10, 20 and 30 days after the manufacture of the sample in the form of standard density with attention The specimen was made into a sample density and a single-axial test was carried out on samples. In the sample, it was tried to remove the sample from the soil in terms of density and moisture content in order to obtain the results obtained with the fact that it was very close All samples are 76 mm in diameter and 36 mm in diameter. All tests are carried out for all percentages of contamination and time intervals of three times. The average response was used as the result. The readings taken in this

test are used to record the applied force on the sample for one millimeter vertical displacement. The results are presented below with the graph.

It should be noted that all single-axial tests with different percentages and time intervals were performed according to ASTM D: 2166-10 standard and the device was calibrated before the test was performed.

4-2-1 Soil without contamination

Single-axial test on soil without contamination immediately after taking the sample from the region according to the percentage of environmental concentration in the laboratory after the sample was made, whose strain graph is in accordance with Fig. 4-1.

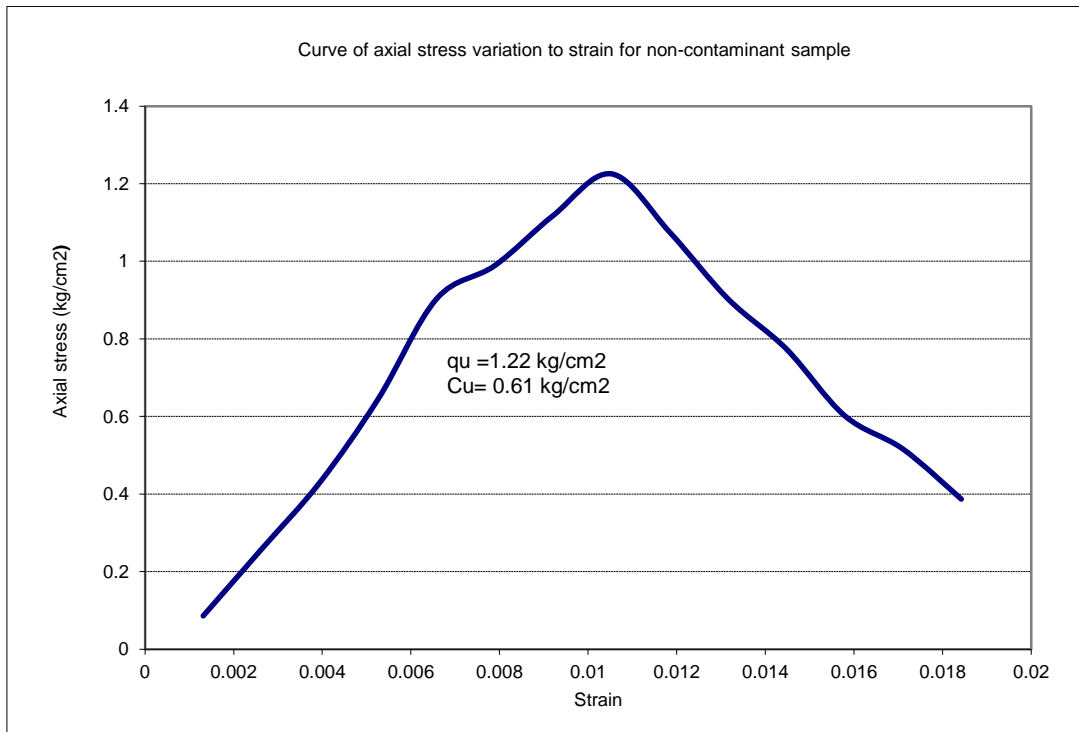


Figure (1.4) Stress-strain curve for non-contaminant sample

As the diagram shows, the maximum soil adhesion in this case is equal to 0.61 kg/cm².

4-2-2 Contamination of 2, 4 and 6 percent of the soil after ten days

As mentioned in the previous chapter, the samples are removed from the nylon after the mentioned time period and then mixed and then, according to the previous state, they are dense and sampled. The stress-strain curves associated with this period are presented in the hundreds of contamination mentioned in Fig. 2-4, which is well visible.

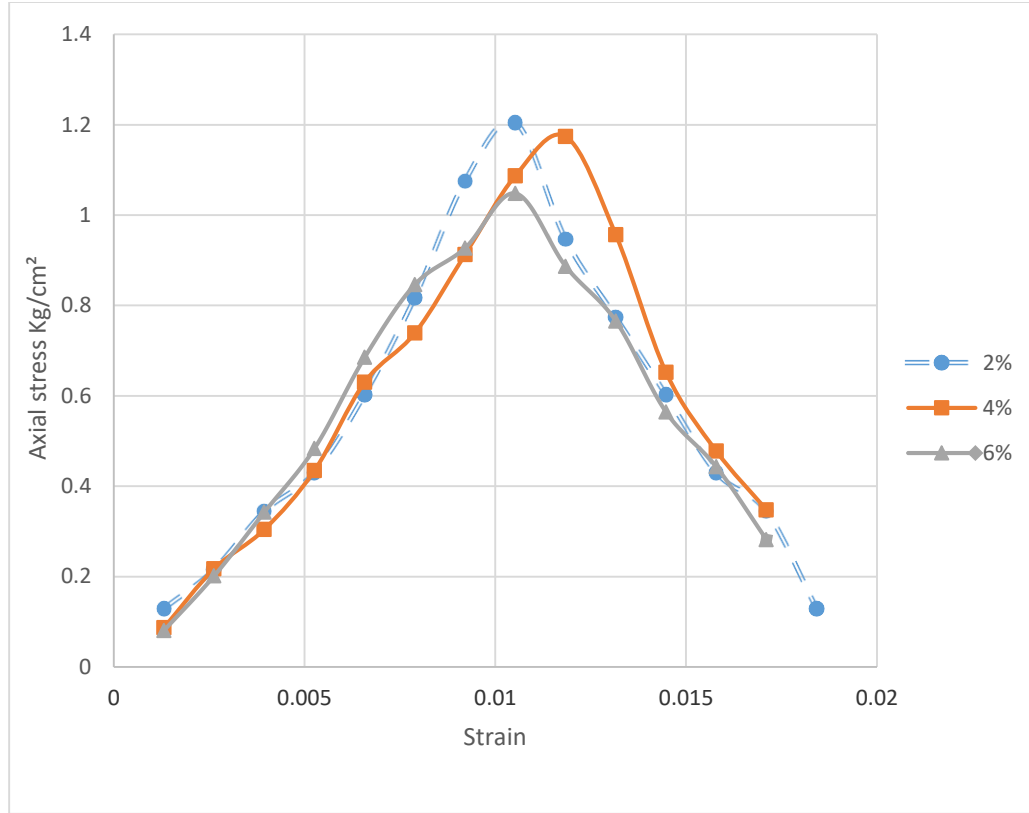


Figure 4.2 shows the stress-strain curve of the ten-day period

As shown in the diagrams and the maximum stress-strain value, the amount of non-drainage adhesion decreased by two percent increase after 10 days from 1.22 kg / cm² to 1.2, and also with an increase in the percentage of contamination of 4 and 6% in the same period, the adhesion was 1.17 and 1.488, respectively, which can be attributed to the reduction of adhesion.

4-2-2 Contamination 2, 4, 6% of soil after 20 days

In accordance with the previous section, the samples were taken out of the nylon after 20 days and a sample was taken with its stress-strain curve shown in Fig. 3-4. As shown in the stress-strain diagrams, with increasing the time interval of oil disruption with soil within 20 days, the adhesion ratio decreased, so that in the percentage of contamination 2, 4 and 6%, the adhesion values were 0.775, 0.78 And 0.64, which represents a decrease in this time period and the percentage of contamination.

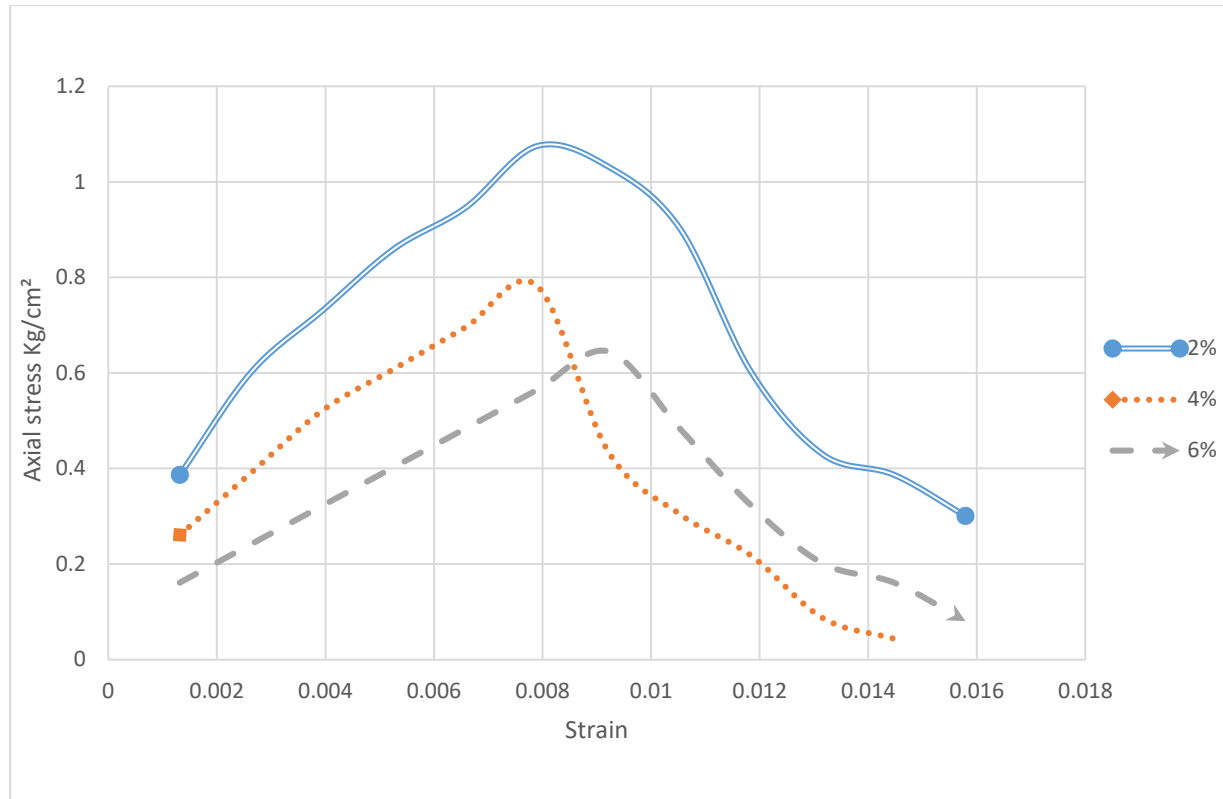


Figure (4-3) stress-strain curve for a twenty-day period

4-2-4 Contamination of 2, 4 and 6% of soil after 30 days

According to the previous state, the soil was extracted from the nylon after 30 days and the samples were taken. Then, a single-axial stress-strain curve test was obtained as follows. As shown in the diagrams, the amount of adhesion decreased with increasing time and contamination, so that in the percentage of contamination of 2, 4 and 6%, the unloaded soil adhesion was 0.64, 0.47 and 0.4.

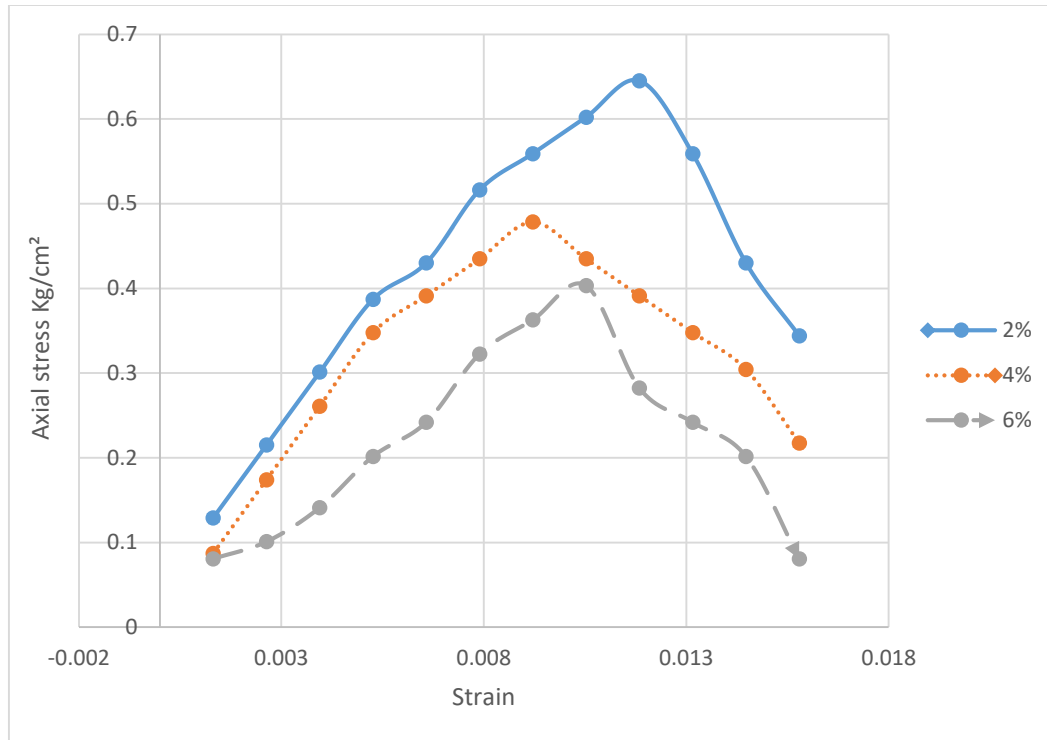


Figure 4-4 shows the strain stress curve of the thirty-day period

4-2-5 Analysis of unidirectional test results is not enclosed

As the stress-strain graphs and its maximum value are known, increasing the percentage and time interval of the effect of contamination on soil texture decreases compressive stress and consequently shear stress (adhesion). The cause of cutting in shear stress is the combination of two physical and chemical effects of crude oil. Physically, the presence of crude oil facilitates the slippage of soil grains on each other during pressure, which reduces the shear stress of the soil. From the chemical point of view, clay soils are usually absorbed more by water than by oil absorption, which is due to the clay's water-friendliness. For a clay sample, the amount of interlayer variation for different solutions varies, indicating a difference in the interest of these soils in absorbing different compositions. The largest volume variation is for ordinary clay, due to the clay fluid properties. While results for hydrocarbon samples often show hydrolysis and adsorption of organic compounds. This decrease in inflation actually provides space for easier soil movement. In the following, a summary of the results of the univariate test is presented in Table (4.1), which relates to unloaded soil adhesion values for a period of ten, twenty-thirty days.

Table (1.4) Unloaded soil adhesion values for ten, twenty-thirty days

Percentage of contamination \ Time period	10 Days	20 Days	30 Days
2 %	1/22	1/075	0/64
4 %	1/17	0/78	0/47
6 %	1/048	0/64	0/4

4-3 Effect of oil contamination on shear strength of soil under direct shear test

In a straight shear test, the shear strength of a test piece of soil is determined on a marked fracture plane. Typically, in this case, in order to determine the effect of vertical stress on the rupture plane on soil resistance and determination of the rupture failure in a particular case, the determination of the Mohr-Coulomb shell (three test pieces) parameters is tested in different vertical pressures. In this test, the test specimen is placed inside the cutting box and the vertical stress applied to the test piece is applied. The cutting box consists of two square shaped molds or two metal rings that are on each other. After the end of the test fixation, due to the vertical stress applied, the two frame forms of the cutting box are moved relative to each other with a fixed displacement rate, and during the movement, the force required to apply this displacement is measured.

In this study, after single-dip irrigation experiments on oil-contaminated soil, direct cutting experiments were carried out to investigate further and compare the results obtained with single-duct test. Figure 4-5 shows a sample made in a cube with dimensions 60x60 and 20mm height.



Figure (4-5) Shear box

For all samples, the soil moisture content was 20% and the maximum dry weight was 74.1. The normal stresses of 17.5, 37.5 and 57.5 KPa have been applied in this test. The aim of this experiment is to obtain a shear stress diagram for vertical stress, which allows the angle of friction of the soil as well as soil adhesion in the pollutants 2, 4, and 6, and time intervals of 10, 20 and 30 days. In this experiment, three samples were tested for each level of pollution at each time interval and the test was repeated three times for the accuracy of the test, and the average results were used, A total of 90 straight-cut tests were performed. In the following, the curves are presented according to the percentage of contamination and the time interval. Finally, the analysis of the results obtained from this experiment is discussed in the interpretation. It should be noted that this test was carried out in accordance with ASTM D: 3080-10 standard and the device was calibrated before the tests were performed.

3-4-1 Evaluation of soil shear parameters without contamination

The soil was harvested at a depth of one meter above the ground and immediately placed in a compacting device to obtain the specimen, then, with respect to the soil density in the environment, the samples were taken and then the sampling was performed to avoid soil moisture after obtaining Soil was carried out. After making the sample in a direct cutting machine, placed under load of 1, 3 and 5 kg, and strain and applied shear force were recorded and then to calculate the soil resistance parameters including the coefficient of adhesion and the angle of friction inside the soil The shear stress curve of the vertical stress is given in Fig. 4-6.

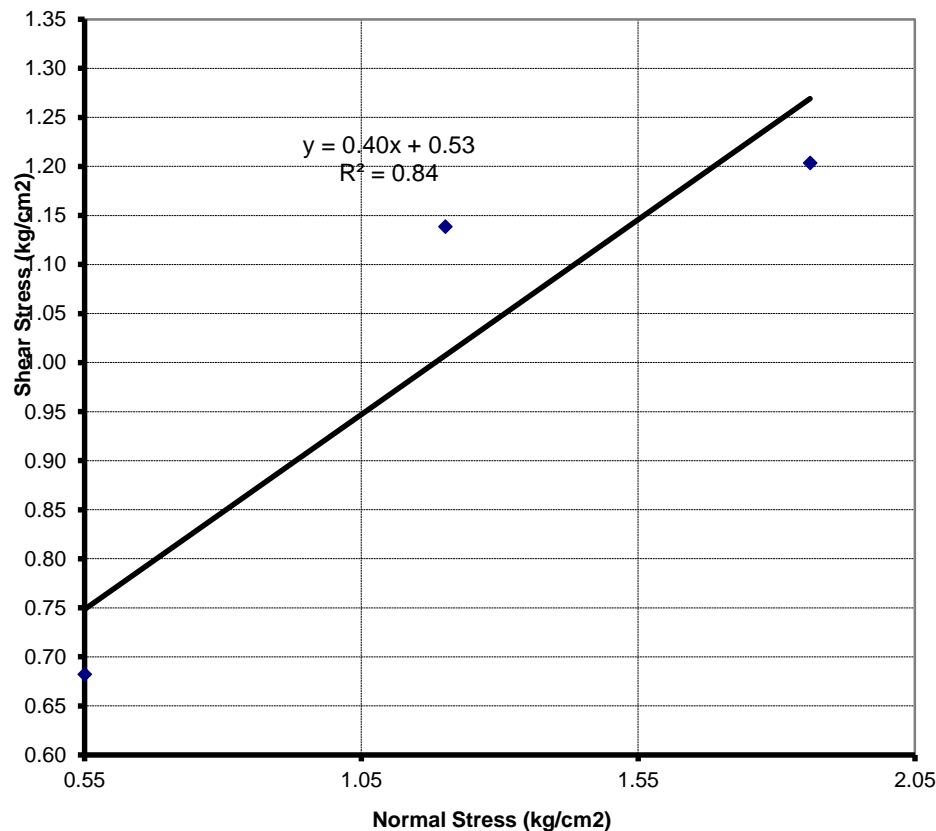


Figure 4-6. Shear stress-normal stress curve in pure soil state

As the diagram shows, the amount of internal friction angle of the soil is equal to 21.67 and the soil adhesion of the non-contamination level is 0.75. Further, the values of these parameters are investigated for the percentages of contamination and the mentioned time intervals.

4-2-3 10-days contamination under percentages 2, 4, and 6

The soil was packed in two layers of nylons and then oil was added to the proportions mentioned. During the ten days, direct cutting was performed and the shear stress curves were determined to determine the resistance parameters. It turned out. The following curves represent the percentages indicated.

4-2-3-1 Contamination of 2 percent

As shown in Fig. 4-7, the internal friction angle of the soil is 23.52 and the adhesion is 0.55, which indicates an increase in the angle of internal friction and a decrease in adhesion.

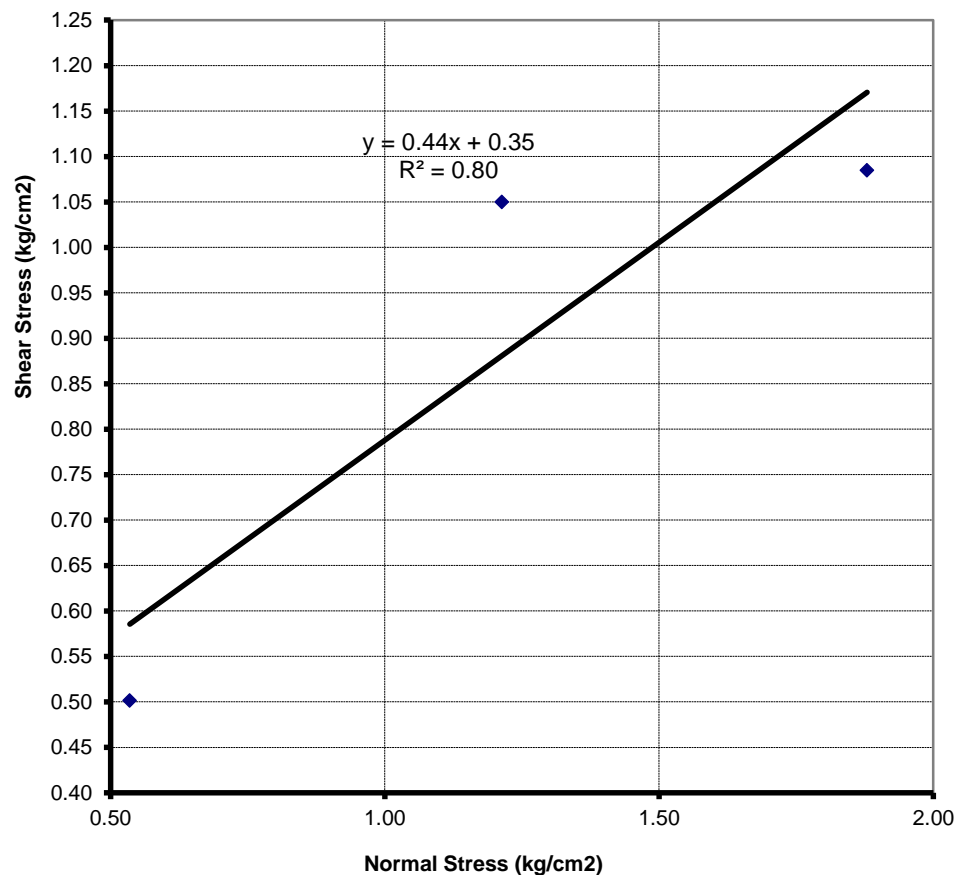


Figure (4-7) Shear Stress-Normal Tension Curve with two-percent contamination for 10 days

4-3-2-2 Contamination of 4 percent

As shown in Fig. 4-8, the internal friction angle is 21.58 and the adhesion is 0.55, indicating a decrease compared to the previous one. Adhesion also shows an incremental trend.

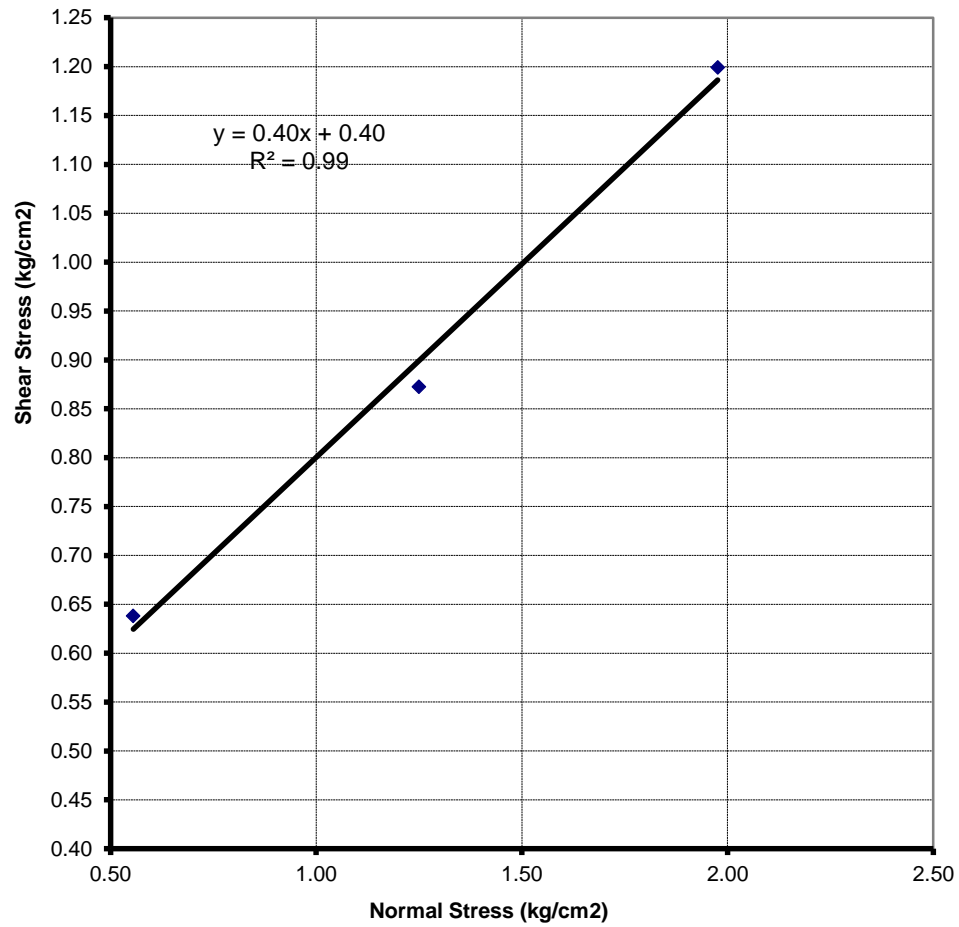


Figure (4-8) Shear Stress-Normal Tension Curve with four-percent contamination for 10 days

4-3-2-3 Contamination of 6 percent

As shown in Fig. 4-9, the internal friction angle of the soil is 17.51 and the adhesion is equal to 0.7, indicating a decrease in the internal friction angle and an increase in adhesion under the influence of contamination of 6%.

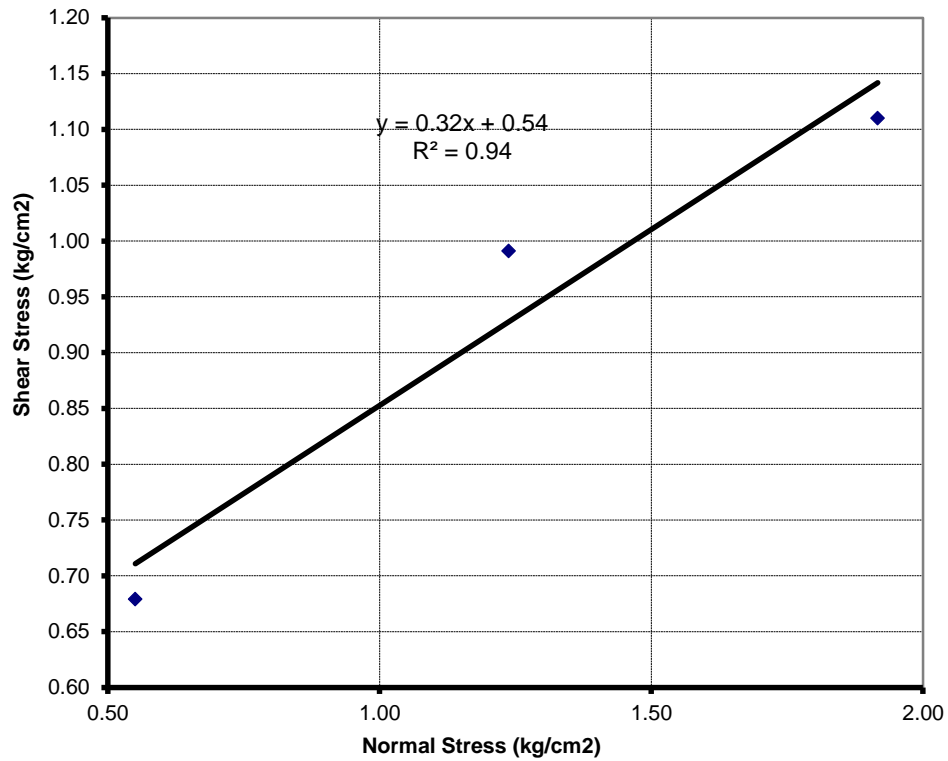


Figure (4-9) Shear Stress-Normal Tension Curve with six-percent contamination for 10 days

4-3-3 20-days contamination under percentages 2, 4, and 6

Soil was collected from the environment in two layers of nylons and then added to the ratios mentioned above and then cut during the mentioned time and the shear stress curves of the vertical tensile were determined to determine the resistance parameters. The following curves represent the percentages indicated.

3-4-3-1 Contamination of 2 percent

As shown in Fig. 4-10, the internal friction angle of the soil is 26.78 and the adhesion is 0.55. Compared to the 10-day state, in the same contamination, the increase of the friction angle is observed for the change in adhesion. It does not occur and is similar to the same percentage of infections in the ten-day period, which indicates that there is no change in adhesion over time.

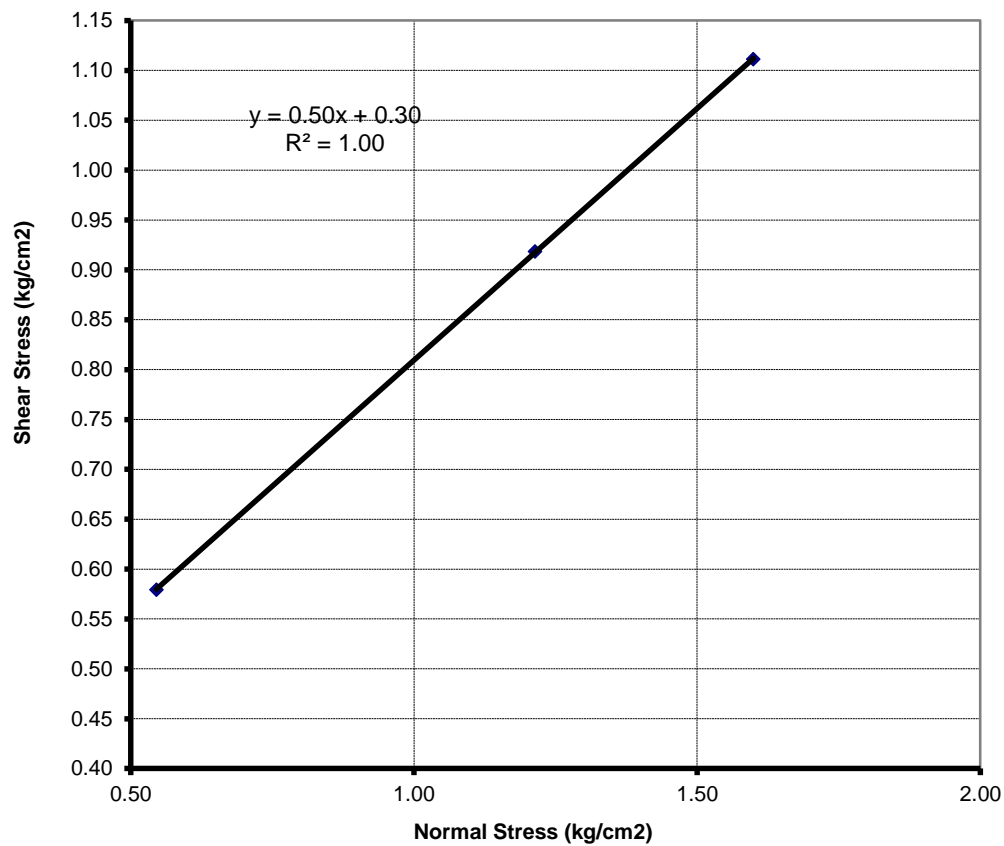


Figure (4-10) Shear Stress-Normal Tension Curve with two-percent contamination for 20 days

4-3-3-2 Contamination of 4 percent

As shown in Fig. 4-11, the internal friction angle of the soil is 23.39 and the soil adhesion in this contamination is 0.6, which reduces the friction angle compared with the previous one, compared with the percentage of contamination. Similarly, during the ten-day period, the adhesion increased and the same percentage of contamination did not change significantly over the ten-day period.

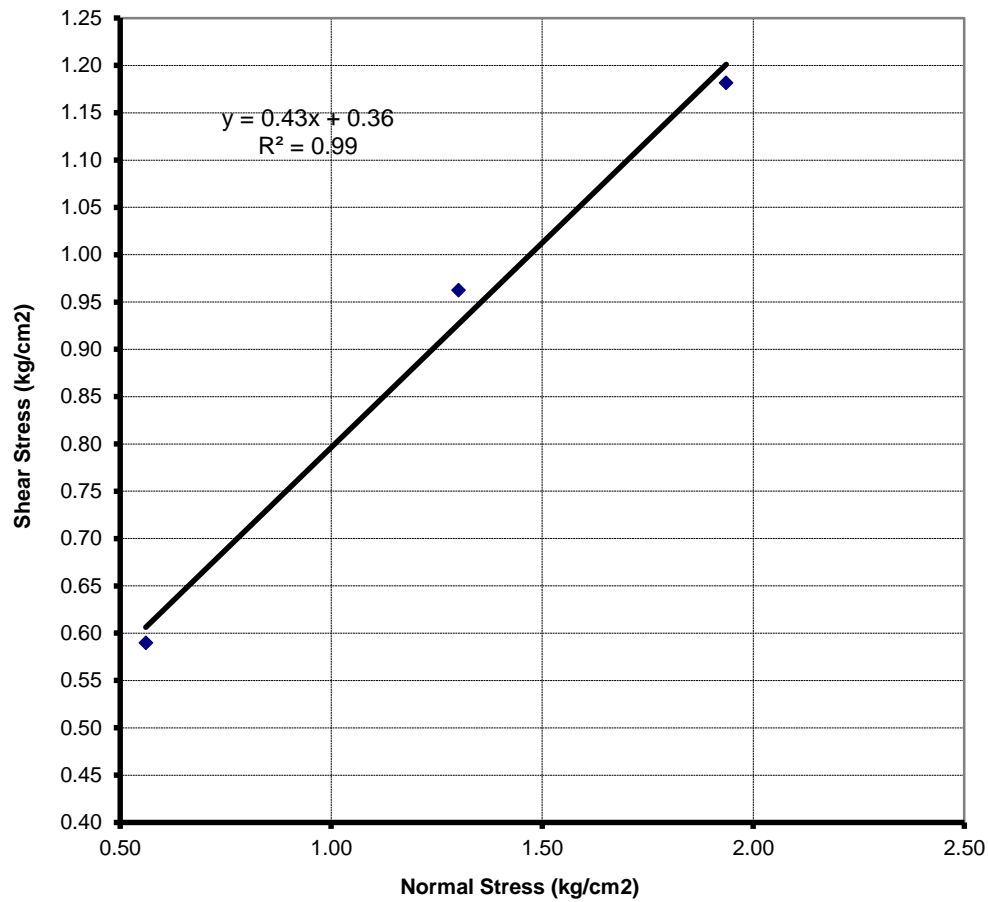


Figure (4-11) Shear Stress-Normal Tension Curve with four-percent contamination for 20 days

3-4-3-3 Contamination of 6 percent

As shown in the diagram, the internal friction angle of the soil is 22.22 and the adhesion is 0.65, which has been increased by decreasing the internal friction angle with similar pollution within the ten day interval. Adhesion has been reported to increase with respect to contamination of 4% and no significant change in the same contamination during the 10-day period.

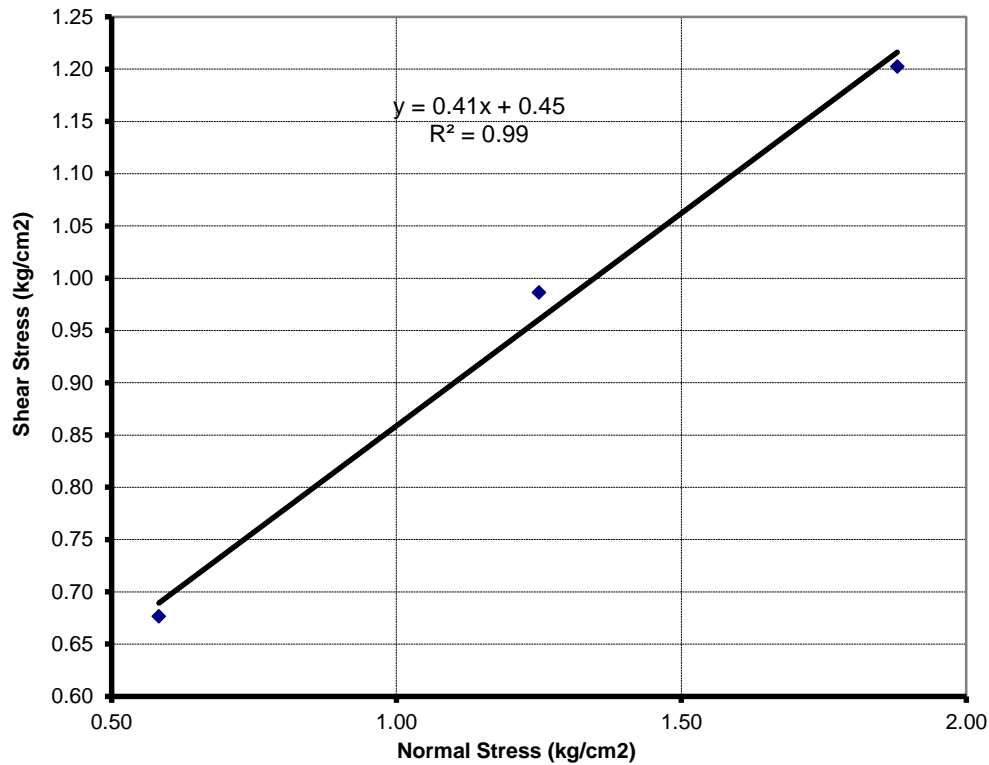


Figure (4-12) Shear Stress-Normal Tension Curve with six-percent contamination for 20 days

4-3-4 20-days contamination under percentages 2, 4, and 6

The soil was packed in two layers of nylons and then added to the ratios mentioned above and, after thirty days, removed from the nylon, and then mixed and, after making the sample, was subjected to cutting, and the curves Shear stress-Vertical tensile strength was determined. The following curves represent the percentages indicated.

4-3-4-1 Contamination of 2 percent

As shown in Fig. 4-13, the internal friction angle of the soil is 21.69 and the soil adhesion is 0.7, which is less than the previous state and is less than twenty ten days in the same percentage of pollution We are faced with a reduction in adhesion, without significant changes in the same contamination in the period of ten and twenty days.

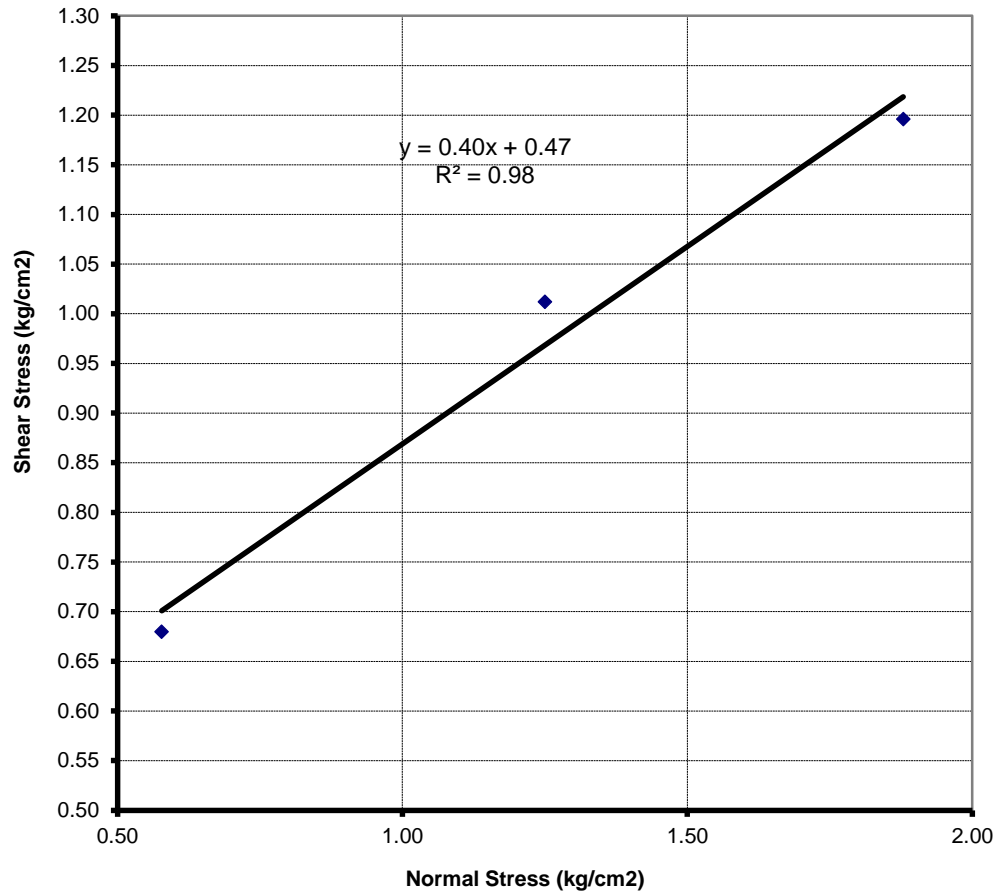


Figure (4-13) Shear Stress-Normal Tension Curve with two-percent contamination for 30 days

4-3-4-2 Contamination of 4 percent

As shown in Fig. 4-14, the internal friction angle of the soil is 21.51 and soil adhesion is 0.6, which is the same as the previous one, as well as the twenty-ten days interval in the percentage of pollution similar to We are faced with a reduction in adhesion, without noticeable changes in the same contamination in the period of ten and twenty days.

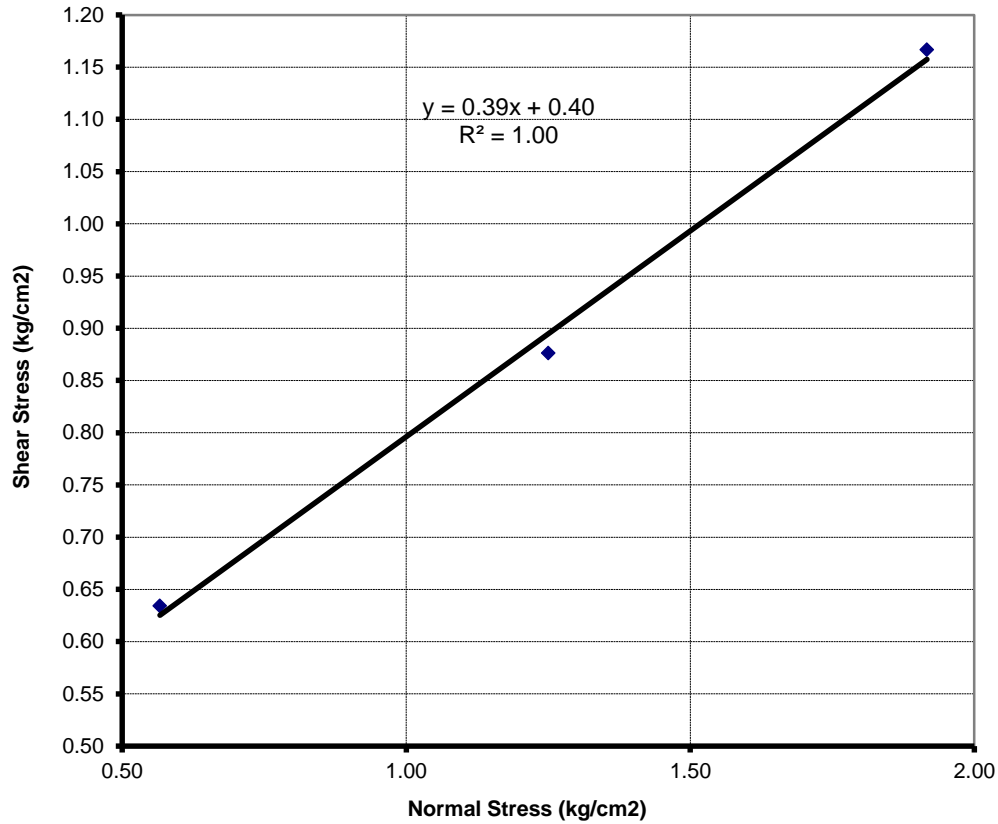


Figure (4-14) Shear Stress-Normal Tension Curve with four-percent contamination for 30 days

4-3-4-3 Contamination of 6 percent

As shown in Fig. 4-15, the internal friction angle of the soil is 9.29 and the soil adhesion is 0.75, which is similar to that of the previous and also the twenty-ten days interval in the percentage of pollution similar to We have a decrease, for adhesion, without changing the perceptible change in percentage of contamination of the same state of ten and twenty days.

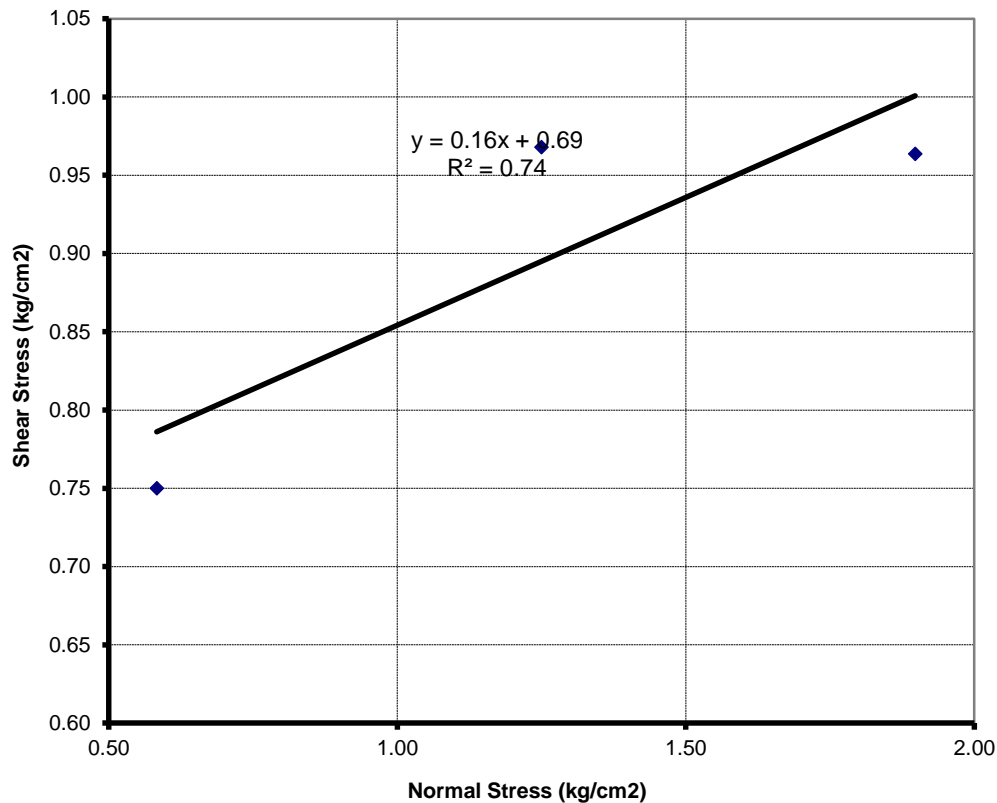


Figure (4-15) Shear Stress-Normal Tension Curve with six-percent contamination for 30 days

5-3-3 Analysis of the results of the direct shear test

As shown in the diagrams and numbers stated in the previous sections, the internal friction angle of the soil with a significant increase in the percentage of contamination is not significant to 2%, but in the four or six percent, we see a numerical reduction of the friction angle, which decreases the shear strength of the soil. Also, according to the numbers obtained, the time interval of the impact of the pollution on the soil is not significant and the changes in the angle of friction depend on the amount of pollution that causes the soil to weaken. Concerning adhesion, as the graphs show, and the numbers in the previous section, with increasing soil infestation, soil adhesion is initially reduced, and then in the number of pollution, it has increased by 4 and 6 percent. Other results of this experiment are not affected by the interval. One can point out the amount of adhesion.

The reason for decrease in shear stress is the combination of two physical and chemical effects of crude oil. Physically, the presence of crude oil facilitates the slip of the soil grains onto each other during cutting, which reduces the shear stress of the soil. From the chemical point of view, swelling of ordinary clay soils with water absorption is more than oil absorption, which is due to the clay's wateriness. For a clay sample, the difference in interlayer spacing for different solutions varies, which indicates the difference in the interest of these soils in absorbing different compositions. The largest volume variation is for ordinary clay, due to the clay's hydrophilic properties. While the results for hydrocarbon specimens show the predominance of hydrolysis and adsorption of organic compounds. This decrease in inflation actually provides space for easier soil movement.

In the same way, the impact of pollution on soil resistance can be summarized as follows: the samples, due to contamination with the gas oil, lose their ductility, in other words Nano plastics. Because the charged particles of the soil are surrounded by oil, oil prevents the effect of water on clay particles, which tends to change the behavior of clay to sand. With changes in percentage of contamination, changes in adhesion and internal friction angle show non-uniform behavior. This means that in 15% of the internal friction angle, the size of the internal friction suddenly increases and the adhesion is reduced at once, it seems that changes in these parameters in contaminated conditions should not simply take into account the ascending or descending trend and even from an optimal point in the characteristics of soil contaminated, which, of course, requires more testing.

Although changes are not uniform, but overall, by comparing 4 and 6 percent of oil pollution, it can be said that increasing the percentage of oil contamination decreases the amount of internal friction angle and increases adhesion. Maximum shear stress decreases with increasing oil contamination. With the increase of normal stress in oil-contaminated samples, the decrease in the shear stress is also increased. In the following tables (2-4) to (4-4), the numbers obtained from the experiments are presented to compare the friction angle and adhesion in percentages of contamination and time intervals.

Table (2-4) contains numerical values for 10-day contamination

20-day contamination	2 %	4 %	6 %
Internal friction angle (°)	23/53	21/58	17/51
Adhesion (kg/cm ²)	0/55	0/6	0/7

Table (3-4) contains numerical values for 20-day contamination

20-day contamination	2 %	4 %	6 %
Internal friction angle (°)	26/78	23/39	22/12
Adhesion (kg/cm ²)	0/55	0/6	0/65

Table (4-4) contains numerical values for 30-day contamination

30-day contamination	2 %	4 %	6 %
Internal friction angle (°)	21/69	21/51	9/28
Adhesion (kg/cm ²)	0/7	0/72	0/75

4-4 Investigating the Effect of Oil Pollution on Soil Convergence under Consolidation Test

This test is a suitable method for calculating the amount and speed of consolidation of soil under one-dimensional conditions under stress loading. In this test, a test piece is placed under axial loading under limiting conditions. The load is applied stepwise to the test piece. At each stage of loading, while measuring the height changes, the test piece can be consolidated (cavitation water is removed). The measured values are used to calculate the effective porosity-stress relationship as well as the consolidation velocity.

Also, in the test, loads of 0.5, 1, 2, 4, 8 and 16 kg were loaded and reversed for loading, which applied to the pressure sample for 24 hours and in intervals according to standard ASTM D: 2435-10 Readings are read. Soil taken from the environment was placed in two layers of nylons to prevent moisture loss and added to the amount of 2, 4 and 6% of oil in proportion to weight, and consolidated in the 10, 20, and 30 days' intervals tested. It should be noted that the same prototype has been made of uniaxial samples and direct cutting, which is not mentioned again. Also, after the test, the consolidation of the sample in the warm home was dried for 24 hours and then weighed to determine the specific gravity. The aim of this experiment is to obtain consolidation parameters for estimating the impact of pollution and time intervals on soil concentration. The parameters studied in this section are compaction index (C_c), inflation index (C_s), moisture content ($w\%$), specific gravity (γ) and porosity (e), which are described below.

4-4-1 Soil without contamination

In order to obtain soil seeding parameters in a non-contaminated soil, the soil is collected in a compact form, according to the density of the soil, and the sample is taken from the sample, then the consolidation test was carried out and as described in the previous section During loading and loading, the readings were taken and the porosity-logarithmic curve of pressure was plotted for the desired soil and the required parameters were taken. The results are shown in Fig. 4-16 and Table 4-5.

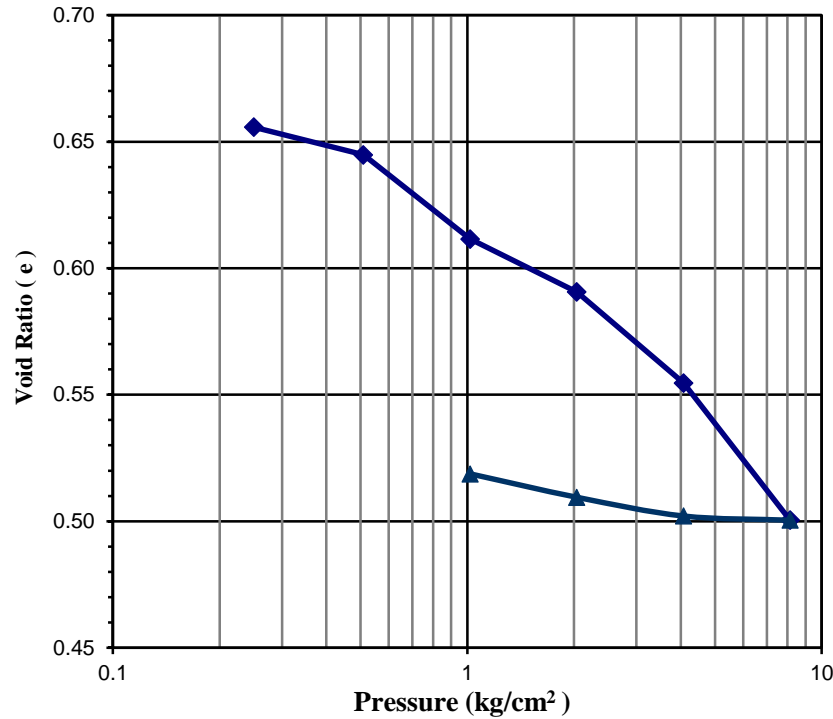


Fig. 4-16 Porosity-pressure logarithmic curve for pure soil

Table (4-5) Numerical values of settlement parameters for pure soil

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
20	0/66	1/61	0/15	0/025

4-4-2 10-day contamination under percentages 2, 4 and 6

The soil was packed in two layers of nylons and then the oil was added to the ratios and after 10 days the test was consolidated and the porosity curves - pressure logarithm were plotted to determine the soil parameters. In the following sections, the curves are presented in the following sequences.

4-4-2-1 Contamination of 2 percent

As shown in Fig. 4-17 (gradient diagram), the compression index in this case is equal to 0.16 and the inflation index is 0.122, which is increased as compared to the non-contamination state, which indicates an increase in seismicity. Also, the moisture content in this state is 19.3, which is lower than the previous one. The soil tolerance is 0.46 in this case. Porosity reduction is another result of this experiment. Specific gravity is equal to 1.84, which indicates an increase.

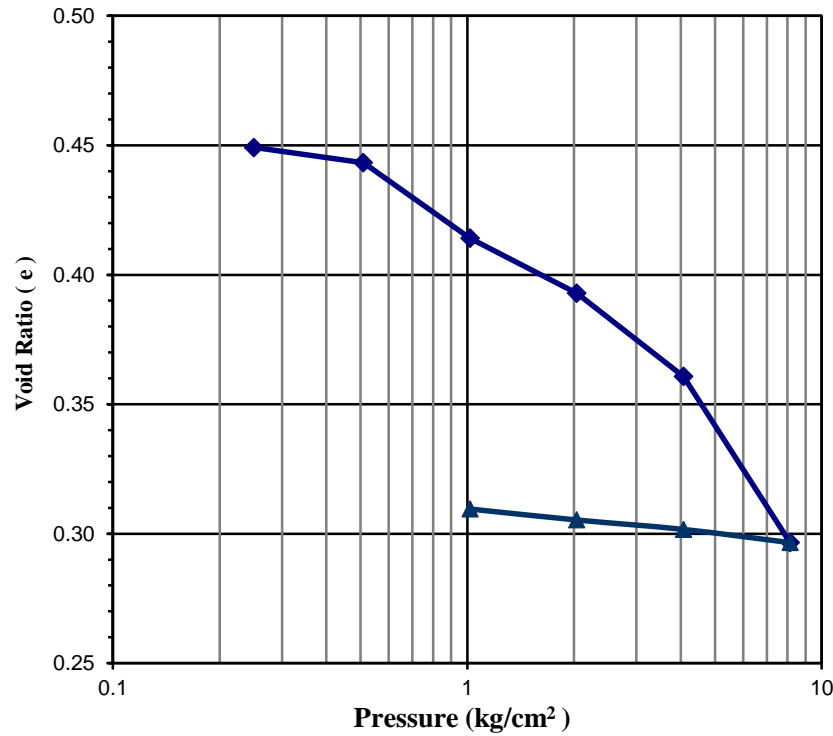


Figure 4-17 Porosity-pressure logarithmic curve for contamination of two percent, ten days

Table (4-6) Numerical values of settlement parameters for contamination of two percent, ten days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
19/3	0/46	1/84	0/16	0/050

4-4-2-2 Contamination of 4 percent

As shown in Fig. 4-18, the gradient of the graph, the compression index in this case is equal to 0,167 and the inflation index is 0,666, which has increased as compared with the non-contamination state, which indicates an increase in the congestion. Also, the moisture content in this mode is 20. Which is increased compared to the previous state. Soil irritation in this case is equal to 0.25. Porosity increase is another result of this experiment. The specific gravity is also 1.76, which shows a decrease.

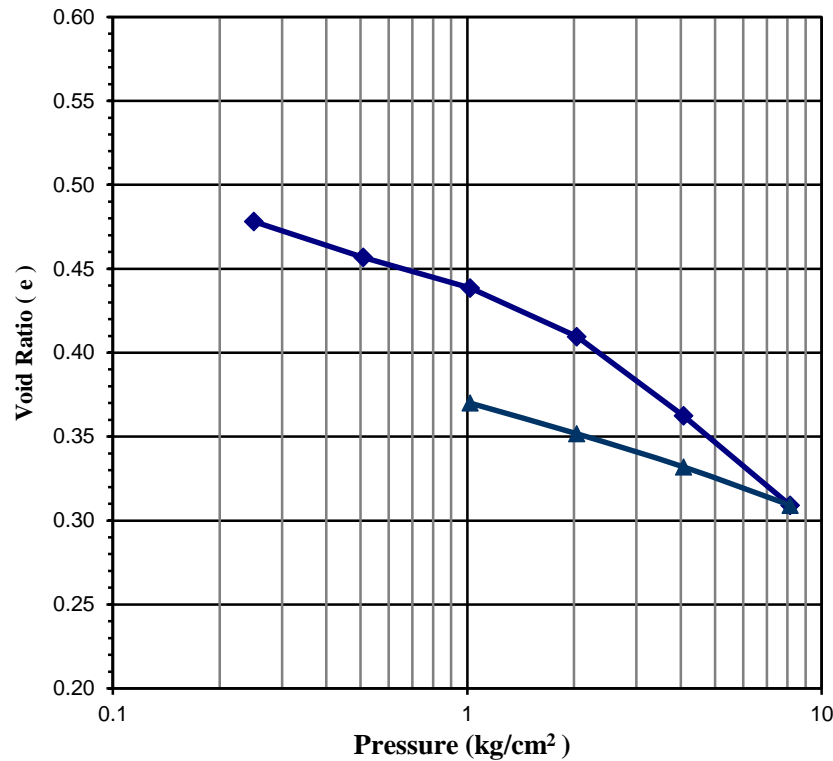


Figure 4-18 Porosity-pressure logarithmic curve for contamination of four percent, ten days

Table (4-7) Numerical values of settlement parameters for contamination of four percent, ten days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
20	0/52	1/76	0/167	0/066

4-4-2-3 Contamination of 6 percent

As shown in Fig. 4-19, the gradient of the graph, the compression index in this case is equal to 0.180 and the inflation index is 0.07, which is increased compared to the previous state, indicating an increase in congestion Also, the moisture content in this case is 21, which is increased compared to the previous state. Soil irritation in this case is equal to 0.62. Porosity increase is another result of this experiment. Specific gravity is equal to 1.65. Shows a decrease.

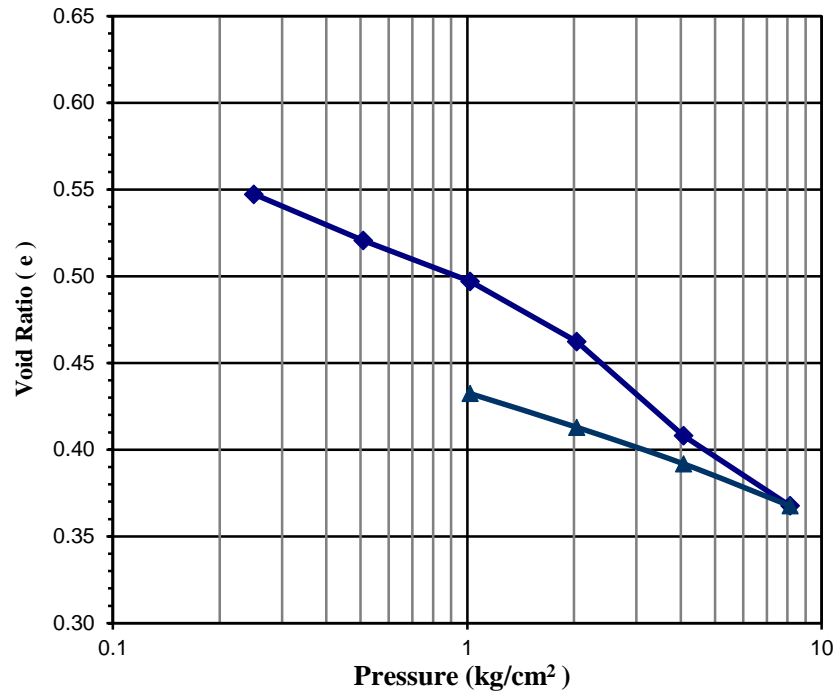


Figure 4-19 Porosity-pressure logarithmic curve for contamination of six percent, ten days

Table (4-8) Numerical values of settlement parameters for contamination of four percent, ten days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
21	0/62	1/56	0/180	0/070

4-4-3 20-day contamination under percentages 2, 4, and 6

The soil was packed in two layers of nylon and then the oil was added to the ratios and after 20 days the test was consolidated and porosity curves-pressure logarithm were drawn to determine the soil parameters. In the following sections, the curves are presented in the following sequences.

4-4-3-1 Contamination of 2 percent

As shown in Fig. 4-20, the gradient of the graph, the compression index in this case is equal to 0.17 and the inflation index is 0.62, which is increased as compared to the non-contamination state, which indicates an increase in seismicity. Also, the moisture content in this case is equal to 17.8. Which is lower than the previous one. Soil irritation in this case is equal to 0.44. Porosity reduction is another result of this experiment. Specific gravity is equal to 1.86, which shows an increase.

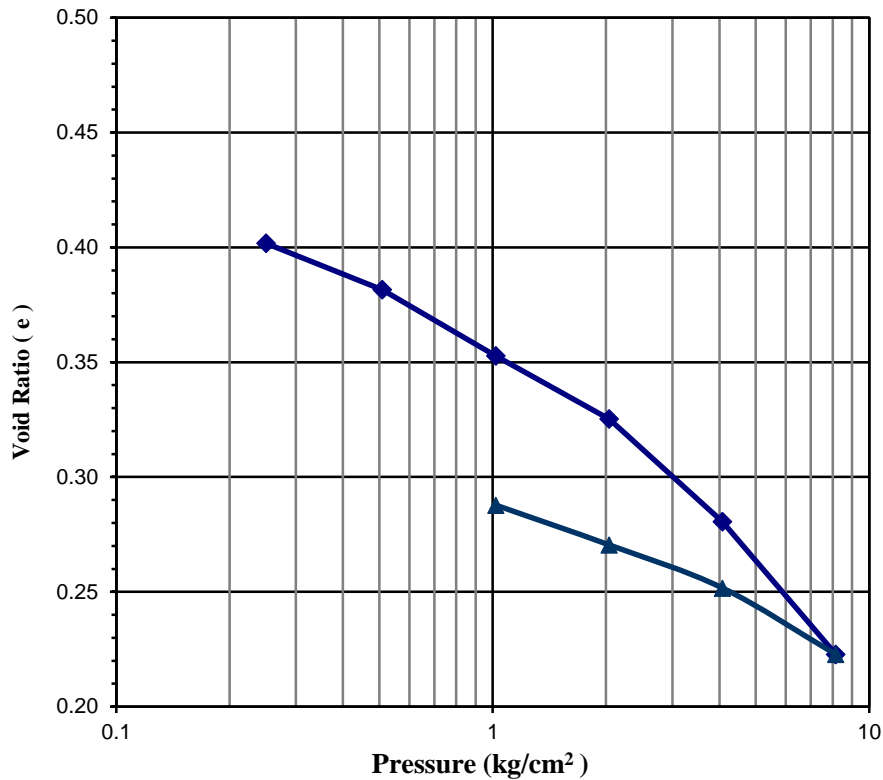


Figure 4-20 Porosity-pressure logarithmic curve for contamination of two percent, 20 days

Table (4-9) Numerical values of settlement parameters for contamination of two percent, 20 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
17/8	0/44	1/86	0/170	0/062

4-4-3-2 Contamination of 4 percent

As shown in Fig. 4-21 (gradient diagram), the compression index in this case is equal to 177/0 and the inflation index is 0.062, which is increased compared to the previous state, indicating an increase in seismicity, as well as The moisture content in this case is 18.9 which is higher than the previous one. The porosity of the soil in this case is 0.5. Porosity increase is another result of this experiment. Specific gravity is also 1.79, which shows a decrease.

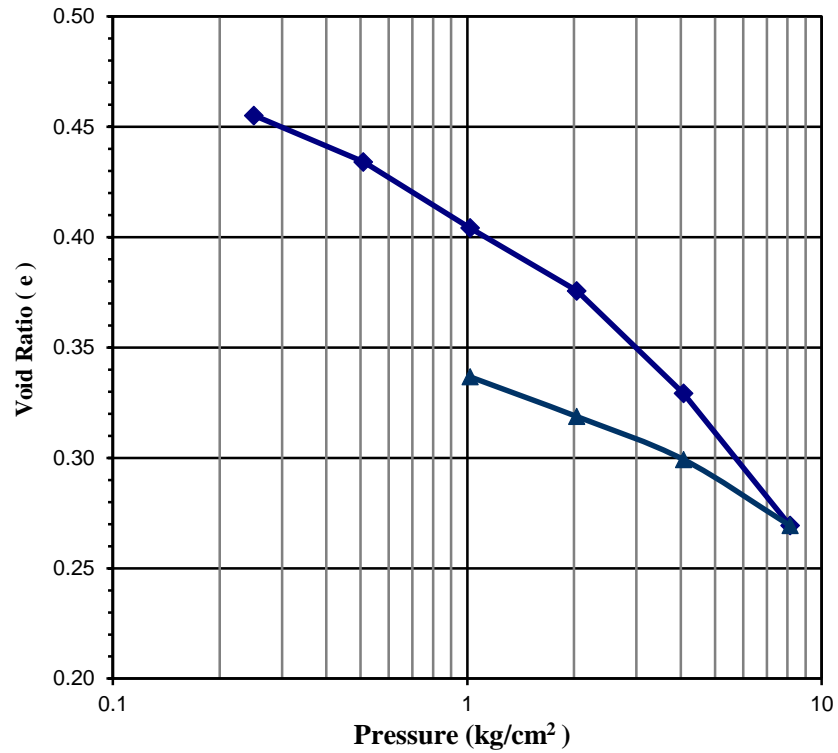


Figure 4-21 Porosity-pressure logarithmic curve for contamination of four percent, 20 days

Table (4-10) Numerical values of settlement parameters for contamination of four percent, 20 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
18/9	0/5	1/79	0/177	0/065

4-3-3-3 Contamination of 6 percent

As shown in the diagram of Fig. 4-22 (gradient diagram), the compression index in this case is equal to 199.1 and the inflation index is 0.068, which is increased compared to the previous state, indicating an increase in seismicity, as well as The moisture content in this case is 19.9, which is higher than the previous one. Soil porosity in this case is equal to 0.58. Porosity increase is another result of this experiment. The specific gravity is 1.7, which shows a decrease.

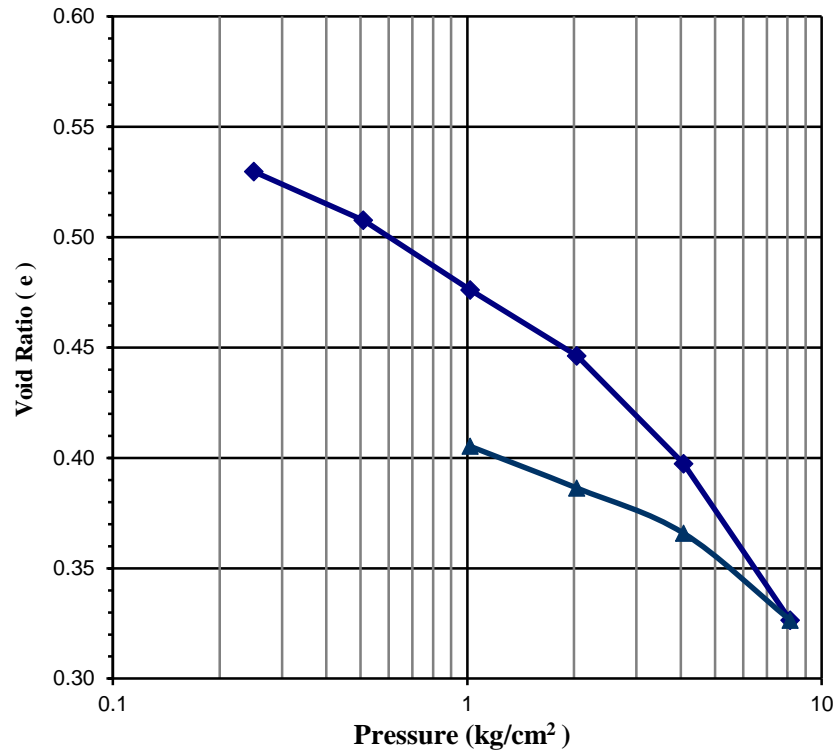


Figure 4-22 Porosity-pressure logarithmic curve for contamination of six percent, 20 days

Table (4-11) Numerical values of settlement parameters for contamination of six percent, 20 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
19/9	0/58	1/7	0/199	0/068

4-4-4 30-day contamination under percentages 2, 4 and 6

The soil was packed in two layers of nylons and then oil was added to the ratios mentioned. After 20 days, under stress testing, porosity-pressure logarithmic curves were plotted to determine the soil parameters. In the following sections, the curves are presented in the following sequences.

4-4-4-1 Contamination of 2 percent

As shown in Fig. 4-23 (gradient diagram), the compression index in this case is equal to 18.07 and the inflation index is 0.646, which is increased as compared to the non-contamination state, which indicates an increase in seismicity. Also, the moisture content in this case is equal to 2/17, which is lower than the previous one. Soil porosity is 0.48 in this case, which is the result of this experiment. The specific gravity is also 1.81, which shows an increase.

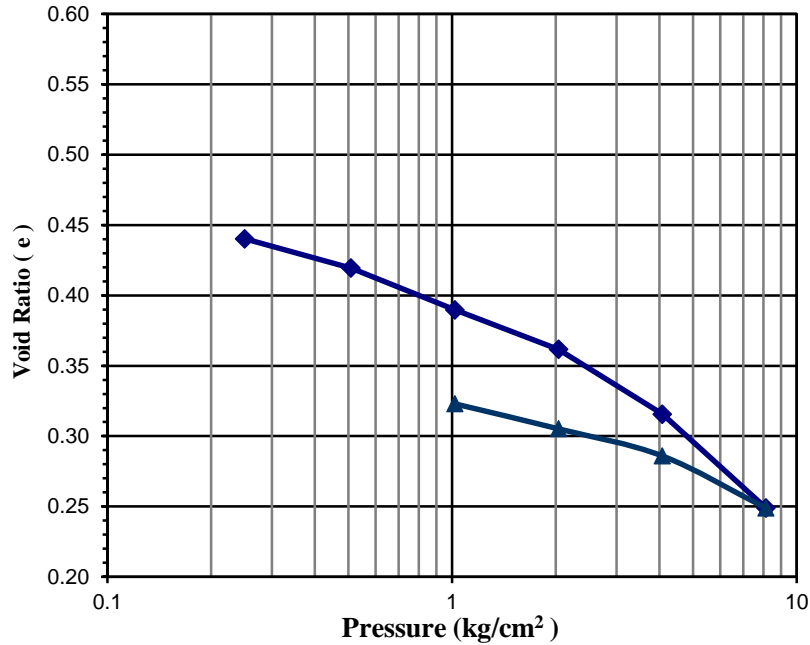


Figure 4-23 Porosity-pressure logarithmic curve for contamination of two percent, 30 days

Table (4-12) Numerical values of settlement parameters for contamination of two percent, 30 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
17/2	0/48	1/81	0/187	0/064

4-4-4-2 Contamination of 4 percent

As shown in Fig. 4-24, the gradient of the graph, the compression index in this case is equal to 219/0 and the inflation index is 0.646, which is increased compared to the previous state, indicating an increase in seismicity, as well as The moisture content in this case is 18, which is increased compared to the previous one. Soil porosity in this case is equal to 0.54. Porosity increase is another result of this experiment. Specific gravity is also 1.75, which shows a decrease.

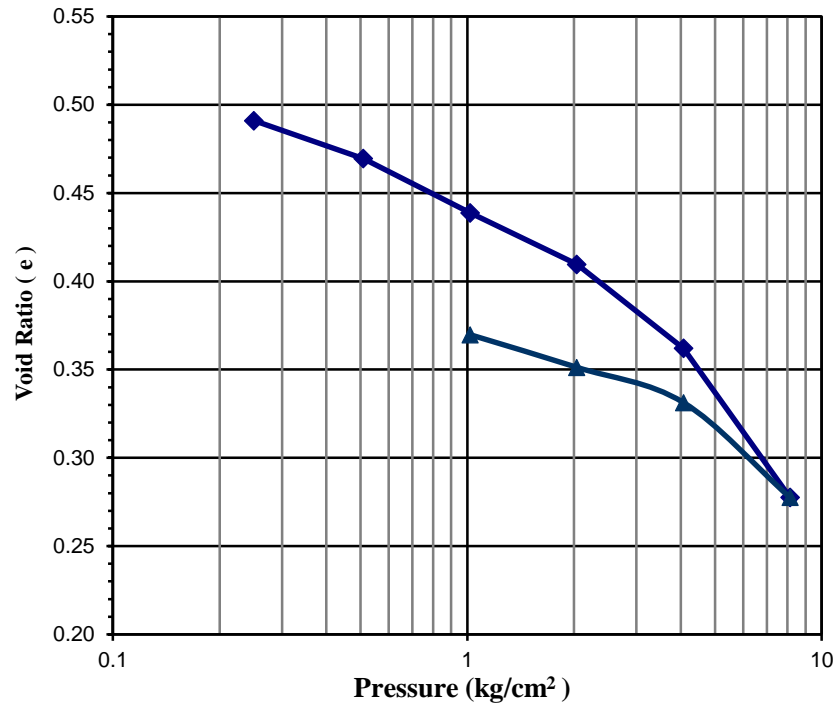


Figure 4-24 Porosity-pressure logarithmic curve for contamination of four percent, 30 days

Table (4-13) Numerical values of settlement parameters for contamination of four percent, 30 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
18	0/54	1/75	0/219	0/066

4-4-4-3 Contamination of 6 percent

As shown in Fig. 4-25, the gradient of the graph, the compression index in this case is equal to 0.227 and the inflation index is 0.077, which is increased compared to the previous state, indicating an increase in the concentration. Also The moisture content in this case is 19.4%, which is higher than the previous one. Soil porosity in this case is equal to 0.63. Porosity increase is another result of this experiment. Specific gravity is equal to 1.65, which indicates a decrease.

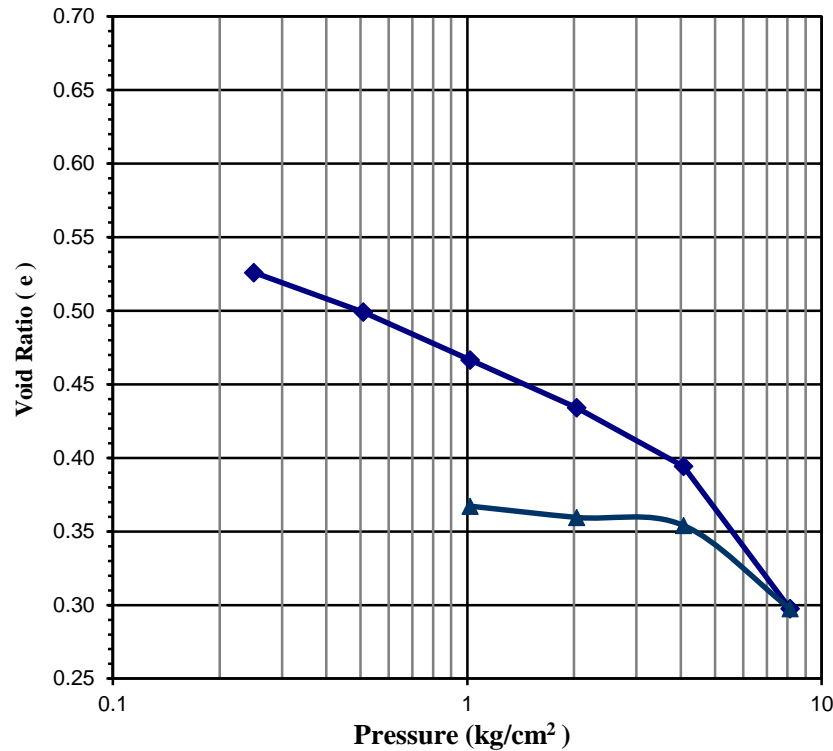


Figure 4-25 Porosity-pressure logarithmic curve for contamination of six percent, 30 days

Table (4-14) Numerical values of settlement parameters for contamination of six percent, 30 days

Moisture percent	Porosity	Special Weight	Compression Index	Inflation index
19/4	0/63	1/65	0/227	0/070

4-4-5 Analysis of consolidation test results

As the results described in previous sections and diagrams show, increasing the percentage of pollution increases the compression and inflation index, which also affects the increase and accelerates the process of increasing the soil resistance and The steep gradient of the porosity-pressure curve is increasing soil compaction.

Experiments show that by increasing the amount of soil pollution with oil, the maximum dry weight of the soil increases initially, but decreases with increasing pollution, but the optimum moisture content is increased .The decrease in dry gravity due to the fact that the presence of oil in the soil due to its viscosity prevents the movement of water between soil particles and provides less sliding surfaces for movement, and therefore does not allow soil to accumulate Resulting in a higher moisture content to reach the maximum dry weight. Reducing the unit weight of the dry matter volume leads to a decrease in the amount of soil contamination over time and the soil loses

its initial density and makes it more compact. It will be. On the other hand, increasing the amount of contamination increases the psychological limitations of the soil. This can be indicative of the sticky effect of the presence of oil in the fine grain soil. Also, porosity initially decreases but increases with contamination and does not have an effect on it due to the placement of oil molecules in the free space of particles of soil under the influence of pressure.

CHAPTER

5

Conclusion

5-1 Introduction

In this thesis, the effect of oil pollution on the resilience and clogging of clay in the Babol area was investigated. The oil used is the specification listed in the second chapter, and the soil was taken from the Babylonian area at a depth of one meter from the soil and brought to the laboratory site. The soil was graded in a clay with low plasticity.

In order to study the effect and the rate of reduction and coupling on this soil, single-axial compressive strength, direct cutting and consolidation tests were carried out at different time intervals. In the past year, the results of these experiments and their analysis in the form of tables and diagrams were presented. In this chapter, the overall results of these experiments will be discussed and, finally, suggestions for future research will be presented.

5-2 General conclusions

5-2-1 Primary soil profile

- Soil used in this study has 29% coarse grains and 71% fine grains, which are classified according to low clay unaffiliated clay classification.
- The moisture content of the investigated soil is 20 and its specific density is 2.71.
- Soil of research has a psychological limit of 25 and a plastic limit of 15, with a plastics index of 9.
- The desired soil has a density of 53.07 and a dry gravity of 2.2.

5-2-2 Testing unconstrained compression strength (single axial)

In this study, with addition of 2, 4 and 6% by weight of oil to soil in 10, 20 and 30 days intervals, with soil moisture content of the uniaxial test environment, from each state, in total 10 tests were carried out.

By increasing the percentage and time interval of the effect of contamination on the soil texture, the compressive stress and consequently the unpressurised compressive strength (adhesion) are reduced. In the case of non-contamination, the numerical value of the unpressurised compressive

strength is equal to 1.22 and in the case of six percent contamination in the 30-day interval, this value is 0.4, which is reduced by about 33%.

The cause of decrease in shear stress is the combination of two physical and chemical effects of crude oil. Physically, the presence of crude oil facilitates the slippage of soil grains on each other during pressure, which reduces the shear stress of the soil. From the chemical point of view, clay soils are usually absorbed more by water than by oil absorption, which is due to the clay's water-friendliness. For a soil sample, the difference in interlayer spacing for different solutions varies, which indicates the difference in the interest of these soils in absorbing different compositions. The largest volume variation for ordinary clay is due to the clay fluid's properties. While the results for hydrocarbon specimens show water absorption and absorption of organic compounds predominantly. This reduction in inflation actually provides space for easier soil movement.

5-3-2 Direct shear test

The obtained samples were mixed with oil in accordance with the preceding sections in terms of weights of 2, 4 and 6%, and were tested for 10, 20 and 30 days intervals to determine soil resistance parameters.

The internal friction angle of the soil with an increase in the percentage of contamination has not significantly changed to 2% relative to the non-pollutant state, but in the four or sixths of the year, we see a numerical reduction of the friction angle, which decreases the shear strength of the soil, also due to the numbers The handwriting indicates that the effect of the time interval of the impact of soil pollution on the friction angle is not significant and the changes in the friction angle depend on the amount of contamination that weakens the shear strength of the soil.

- As the percentage of pollution increases, soil adhesion is initially reduced, and then there are four and six upward trends in the number of pollution. Other results of this experiment can be mentioned not having an effect on the amount of adhesion.

5-2-4 Consolidation Test

The obtained samples were mixed with oil according to the preceding sections in terms of weights of 2, 4 and 6% and were tested for 10, 20 and 30 days' intervals for determination of soil susceptibility parameters.

- Soil compaction index increases with increasing contamination level. In non-contamination mode, this value is equal to 0.15 and in the case of 2 percent pollution after 10 days to reach 16. Also, the time interval has no significant effect on this index, but Over time, this index increases with increasing contamination.

- Soil inflammation index increases with increasing contamination level. In non-contamination, this value is equal to 0.25 and in case of pollution 2% after 10 days to reach 0.50. Also, the interval does not have a significant impact on this index, but Over time, as the percentage of pollution increases, this index increases and, consequently, the convergence increases.

- The moisture content of the soil decreases with increasing of 2% after 10 days, then increases in four and six percent. Also, during the twenty-three days, the moisture content of the sample increases.

- The porosity of the sample in a two-percent contamination period in the 10-day period initially decreases and then increases with increasing contamination. Time does not have much effect on

porosity, but generally increases porosity.

- Dry soil dry weight is initially increased by adding two percent of the infection after ten days and decreases in percentages by four and six percent, which continues in periods of twenty-thirty days, which, in general, are independent of the range Time decreases.

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